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HYDROGRAPHY

OF THE

AMERICAN ISTHMUS.

BY

ARTHUR POWELL DAVIS.

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HYDROGRAPHY OF THE AMERICAN ISTHMUS.

By Arthur Powell Davis.

GENERAL CHARACTERISTICS OF CENTRAL AMERICA.

PHYSIOGRAPHY.

The geologic and topographic features of Central America are distinct from those of both North and South America.

The continental cordillera, or backbone of North America, abruptly terminates in southern Mexico, just north of the Isthmus of Tehuantepec, and if continued in its general direction, would extend into the Pacific Ocean, west of the American Isthmus. On the south, the Andean cordillera terminates in northern Colombia, far to the east of the isthmus. R. T. Hill describes this region as follows:

> The Caribbean region, including Central America, the Antilles, and the Windward Islands, and most of the Venezuela and Colombian coast of South America, is one of east-and-west folded sedimentaries plus accumulations of volcanic intrusions and ejecta; but instead of dominating a continental region, practically constitutes a mountainous perimeter surrounding the depressed basin of the Caribbean.[a]

Thus, the natural division of Central America includes the region from the Isthmus of Tehuantepec to the point where the Isthmus of Darien joins the continental mass of South America. Besides the Mexican territory of Yucatan and the British Colony of Belize, it includes the five republics of Guatemala, Honduras, Salvador, Nicaragua, and Costa Rica. The narrowest part of the isthmus, from the southern boundary of Costa Rica to the South American continent, is a portion of the South American Republic of Colombia, and is properly known as the Isthmus of Panama.

Central America varies in width from 30 to 300 miles. It is mostly mountainous, the continental divide being usually nearer the Pacific than the Atlantic coast. Through Guatemala and Honduras, and for some distance into Nicaragua, the main chain of mountains trends northwest to southeast, and is from 30 to 50 miles from the Pacific. In northern Nicaragua this range bifurcates, and decreasing in altitude, one branch follows close to the Pacific, and the other passes to

[a] Geological history of the Isthmus of Panama and portions of Costa Rica: Bull. Mus. Comp. Zool. Harvard Coll., Vol. XXVIII, No. 5.

the east of the center, and is cut through by the San Juan River. In Costa Rica the chains are again united in a high plateau studded with lofty peaks, which occupies the major portion of Costa Rica, and is almost as distinct from the lower range of the Isthmus of Panama as the latter is from the Andean system to the east. Hence, the mountain system of the Central American region may be divided into four groups, namely, the Guatemalan, the Nicaraguan, the Costa Rican, and the Panaman. The first and third are high and massive, the second low, divided, and broken, and the last, low and narrow. From this follows the location in Nicaragua and Panama of regions of canal possibilities.

Numerous marshes and lagoons are found on both coasts, and both are indented with occasional bays. The Bay of Honduras, on the east coast of Guatemala, is the largest. Many of the deep rivers offer good harbors, but the water is too shallow on the bars to admit large vessels. Boca del Toro and Chiriqui Lagoon are good harbors, but have little commerce. Limon Bay is merely an indentation of the coast, being entirely open to the north. It is used as a harbor for all shipping connecting with the Panama Railroad. The Gulf of San Blas, Caledonia Bay, and the Gulf of Darien occur to the east and south, the last being an extensive body of water.

There are also several gulfs and bays on the Pacific coast. The Gulf of Tehuantepec is the farthest north, and is merely a roadstead. The Bay of Fonseca is one of the fine harbors of the world, being 30 by 50 miles in extent. Its entrance is between the stately volcanoes of Couchagua and Conseguina. Several smaller islands assist in closing the bay. It serves as port for Salvador, Honduras, and Nicaragua, and is commercially very important.

Farther south the Bay of Corinto is a good harbor, and furnishes accommodation for the greater part of the foreign commerce of Nicaragua. San Juan del Sur, a few miles south of the Pacific end of the Nicaragua Canal route, is a small indentation with some commerce.

Salinas Bay lies at the Pacific terminus of the boundary line between Nicaragua and Costa Rica; it is partly within the jurisdiction of each of these countries.

The Gulf of Nicoya is an extensive body of water, and accommodates the Pacific coast commerce of Costa Rica through the port of Punta Arenas.

The Gulf of Dulce is a large landlocked arm of the Pacific in southern Costa Rica, and after passing the small bays of David and Montijo, we come finally to the great Gulf of Panama, over a hundred miles in diameter. Parita Bay is an indentation on the western margin of the gulf; Panama Bay, to the north, is the harbor of the Pacific terminus of the Panama Railway, and is also the terminus of the proposed Panama and San Blas canal routes. San Miguel Bay, on the eastern side of

the gulf, receives the waters of the Tuyra, and is the Pacific terminus of the once proposed Caledonian route.

Guatemala is well watered by numerous rivers and lakes. The largest river is the Matagua, which is over 250 miles long and is navigable for a considerable distance. The Polochic River is 180 miles long and is navigable for 20 miles. The principal lakes are the Flores, Izabel, Amatitlan, Guija, and Atitlan, the latter having no outlet.

The largest rivers in Honduras are the Ulna, in northern Honduras, and the Wanks, which forms the greater part of the boundary line between Honduras and Nicaragua, and is nearly 350 miles long.

The next streams of importance to the southward are the Grande and Bluefields rivers, which rise in the continental divide near the Pacific and drain the major part of northern Nicaragua.

We now come to the San Juan, which in total length and drainage is the largest in all Central America, though its discharge is less than the Ulna or the Wanks. From the source of the Viejo River to the mouth of the San Juan its total length is over 350 miles. This river is of especial interest, as it is the outlet of Lake Nicaragua and the course of the proposed Nicaraguan Canal.

The conditions which favor this region as a site for a canal consist of a large, deep lake 100 feet above sea level, separated from the Pacific Ocean by a narrow strip of land, containing the lowest depression in the continental divide between the Arctic Ocean and the Straits of Magellan, and a large, navigable stream carrying the surplus waters from the lake to the Caribbean Sea. This route is especially fortunate in having at its summit level a magnificent natural reservoir in Lake Nicaragua, fed by an ample drainage basin. This reservoir is useful not only for storing water for operating the locks of the canal, but also for controlling the great floods that could hardly be provided for at practicable cost without its aid. No other route enjoys advantages of this kind.

The high plateau of Costa Rica gives rise to numerous rivers, the San Carlos and Saripiqui flowing into the San Juan, and the Reventazon and several others into the Caribbean, while a number of smaller and relatively unimportant streams empty into the Pacific.

After passing a few insignificant streams we next come to the Chagres, celebrated as the site of the Panama Railroad and Canal. Its headwaters are near the Pacific, and it drains a long strip of the isthmus, flowing nearly parallel to the coast for two-thirds of its course, and emptying into Limon Bay on the Caribbean. Though the isthmus is less than 50 miles wide at its mouth, the Chagres River is over 120 miles long.

To the eastward the Bayana River drains an extensive area into Panama Bay. Like the Chagres, its course is parallel to the coast for most of its length, and it receives many tributaries. Its lower course

occupies the narrowest part of the isthmus, and is the site of the proposed San Blas canal route. At this point the isthmus is only 30 miles in width.

The Tuyra River is the most important stream on the Isthmus of Panama. The drainage of its basin is extremely complicated. Its main branch rises near the Caribbean, and its course for about 80 miles is southeasterly; it then nearly doubles on itself and flows northwest into San Miguel Bay. At its great bend it receives several important tributaries from the south, and its basin covers nearly two degrees of latitude, joining the basin of the Atrato on the south and east.

The Atrato River drains the western part of Colombia into the Gulf of Darien on the Caribbean. Its general course is nearly parallel and very close to the Pacific coast. It is the site of a proposed canal route which lies farther south than that of any other project.

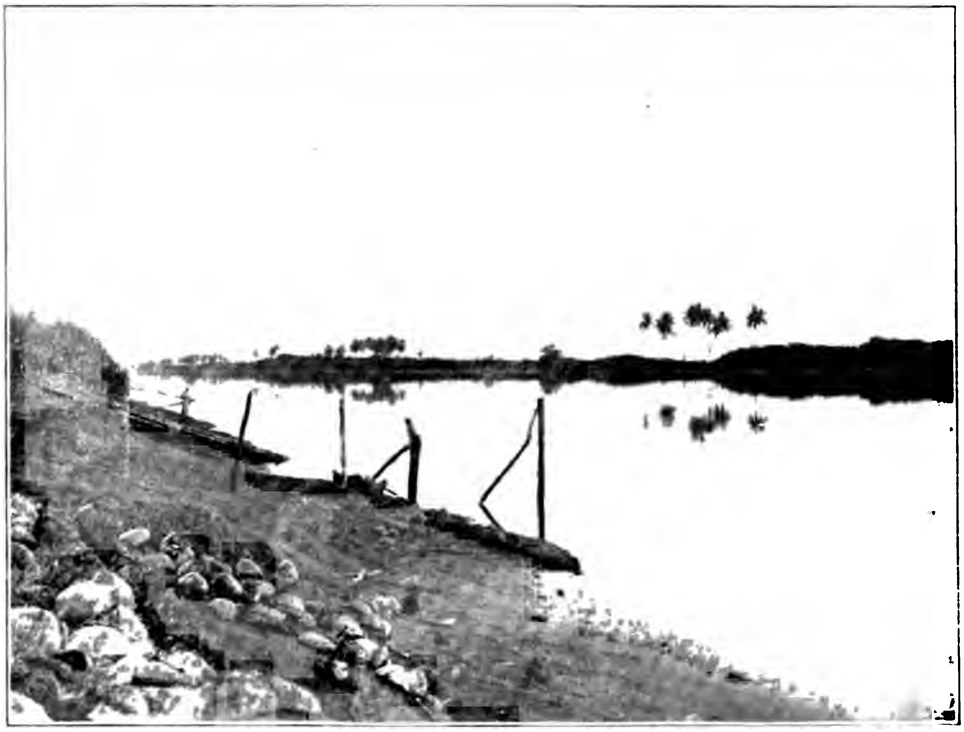
Most of the streams on the Caribbean coast occupy a "drowned" or depressed topography for a considerable distance from the coast, and are consequently tidal in their nature. Though the Caribbean tide is less than a foot, it is plainly perceptible on Bluefields River at Rama, 60 miles from the mouth. The drowned bed of the San Juan extends to Machuca Rapids, over 70 miles from the coast, but the deep channel has been filled with sand by the San Carlos below the mouth of that river, so that it has lost its tidal nature. On the Chagres the tide is daily perceptible at Bohio Soldado, 15 miles from the coast.

TEMPERATURE.

Central America is in the torrid zone, lying entirely between 7° and 22° of north latitude. The climate is therefore tropical, except in the higher mountains, where it becomes cooler under the influence of altitude. In the lower regions, though the mean temperature is high, it is remarkably uniform, there being little change between day and night or with the seasons, and the heat is not excessive. This is especially true of the country near the Caribbean, which is blessed with almost constant trade winds, which have a tempering and very refreshing influence. The relative humidity is high, except on the Pacific slope in the dry season.

Some observations of temperature and relative humidity have been taken in the canal regions and are given in condensed form in the following tables:

A. SARAPIQUI RIVER, COSTA RICA, AT GAGING STATION 5 MILES ABOVE MOUTH.



B. INDIO RIVER, NICARAGUA, NEAR ITS MOUTH.

Temperature and relative humidity at Tola Gage Station, Nicaragua.

[In degrees Fahrenheit.]

Month.	Temperature.			Mean relative humidity.
	Maximum.	Minimum.	Mean.	
1900.				
January	85.0	74.0	79.0	81.0
February	86.5	73.0	81.0	79.6
March	91.5	73.0	82.5	78.2
April	94.0	75.5	84.8	79.0
May	93.0	73.5	82.0	88.2
June	86.5	72.0	80.5	86.2
July	87.0	73.0	78.9	89.4
August	88.0	75.5	80.6	93.2
September	90.0	72.5	80.6	94.0
October	88.0	72.0	79.0	95.2
November	87.0	72.0	79.6	88.6
December	88.0	74.0	79.8	88.6

Temperature and relative humidity at Sapoa, Nicaragua.

Month.	Temperature.			Mean relative humidity.
	Maximum.	Minimum.	Mean.	
1899.				
August	87.0	72	79.6	87.8
September	96.0	70	80.5	89.0
October	94.0	71	78.9	89.4
November	86.0	70	78.5	89.8
December	84.0	72	80.3	87.0
1900.				
January	84.5	73	77.9	88.6
February	86.0	73	79.0	87.8
March	89.0	73	80.3	85.0
April	94.0	75	80.4	82.6
May	93.5	75	82.8	84.6
June	91.5	72	81.3	88.4
July	89.5	74	79.9	89.8
August	87.5	74	80.8	90.0
September	88.0	74	79.8	92.0
October	86.0	71	78.9	94.0
November	86.0	71	78.9	91.8
December	86.0	72	79.1	91.4

Temperature and relative humidity at Las Lajas, near Rivas.

Month.	Temperature.			Relative humidity.
	Maximum.	Minimum.	Mean.	
1898.				
February	80	75	77.7	81.1
March	84	75	79.5	79.3
April	86	77	80.8	79.1
May	91	73	82.1	83.0
June	91	73	81.4	84.8
July	85	74	79.7	86.6
August	85	74	80.7	87.0
September	85	73	79.4	90.4
October	....	....	....	....
November	86	73	79.3	89.7
December	83	73	78.3	91.1

Temperature and relative humidity at Rivas, Nicaragua.

Month.	Temperature.			Mean relative humidity.
	Maximum.	Minimum.	Mean.	
1900.				
January	78.0	75	76.2	86.2
February	79.0	73	77.4	80.8
March	81.5	74	78.5	78.6
April	83.0	79	81.0	80.8
May	83.5	77	80.0	85.4
June	81.0	75	78.6	89.8
July	80.5	75	77.8	89.4
August	81.0	76	79.0	86.2
September	80.5	76	77.8	90.2
October	79.0	74	77.0	91.0
November	80.0	73	77.4	89.0
December	79.2	72	77.7	82.6

Temperature and relative humidity at San Ubaldo, Nicaragua.

Month.	Temperature.			Relative humidity.
	Maximum.	Minimum.	Mean.	
1899.				
September	95	72	81.7	88.0
October	91	72	79.8	91.0
November	91	72	80.0	88.6
December	88	67	78.5	84.6

Temperature and relative humidity at San Ubaldo, Nicaragua—Continued.

Month.	Temperature.			Relative humidity.
	Maximum.	Minimum.	Mean.	
1900.				
January	92	69	79.6	81.8
February	93	69	80.7	79.4
March	99	68	82.9	76.8
April	98	72	86.3	73.8
May	101	75	85.8	79.4
June	94	75	82.9	88.8
July	92	71	81.4	87.2
August	93	73	83.0	84.0
September	93	73	83.1	84.2
October	91	70	80.6	92.4
November	90	71	80.3	85.4
December	91	70	81.2	79.2

Temperature and relative humidity at Fort San Carlos, Nicaragua.

Month.	Temperature.			Relative humidity.
	Maximum.	Minimum.	Mean.	
1898.				
March	88.0	70.0	78.1	58.0
April	88.5	70.5	78.5	79.1
May	91.0	73.0	80.0	85.9
June	90.0	73.0	79.5	88.9
July	89.5	72.0	78.2	88.9
August	89.0	73.5	79.1	89.5
September	90.0	72.5	79.6	87.3
October	90.0	74.0	79.8	88.8
November	88.5	72.0	77.9	90.1
1899.				
January	84.0	69.0	75.9	90.5
February	85.0	66.0	76.9	87.5
March	90.0	70.0	77.6	83.7
April	93.0	69.0	79.6	80.2
May	93.0	71.0	80.4	82.2
June	....	....	....	....
July	86.0	73.0	78.6	91.4
August	87.5	72.0	78.0	90.6
September	89.0	73.0	79.1	89.4
October	86.5	73.0	79.2	90.6
November	84.0	72.0	77.7	89.4
December	84.0	69.0	76.5	91.4
1900.				
January	85.0	72.0	77.6	90.2
February	85.5	70.5	76.9	93.0

Temperature and relative humidity at Sabalos, Costa Rica.

[In degrees Fahrenheit.]

Month.	Temperature.			Relative humidity.
	Maximum.	Minimum.	Mean.	
1898.				
February	90.0	67.0	75.5	87.2
March	90.0	69.0	76.7	84.8
April	89.0	66.0	76.8	85.3
May	89.0	71.0	77.8	87.8
June	89.0	71.0	77.7	90.0
July	89.0	71.0	77.1	92.0
August	87.0	70.0	77.5	91.0
September	90.0	71.0	78.0	87.4
October	90.0	71.0	78.2	87.4
November	88.0	68.0	77.0	90.4
1899.				
January	86.0	66.0	75.2	90.7
February	86.0	64.0	76.0	87.6
March	90.0	68.0	77.1	85.0
April	91.0	67.5	78.2	83.0
May	92.5	70.0	79.4	83.4
June	....	....	....	....
July	88.0	74.0	78.3	91.0
August	92.0	71.5	77.8	91.0
September	91.0	71.5	78.4	89.9
October	91.0	71.0	78.9	89.9
November	87.0	71.0	77.2	87.0
December	84.0	66.0	75.1	91.0
1900.				
January	85.0	66.5	75.3	88.8
February	87.0	68.0	76.0	85.0
March	89.0	67.0	76.8	85.0
April	96.0	67.5	79.5	80.6
May	95.5	72.0	80.4	83.2
June	90.0	71.0	79.0	87.6
July	87.0	72.0	77.0	91.4
August	86.5	72.5	77.0	91.4
September	92.0	72.0	78.7	88.8
October	89.0	71.0	77.8	91.8
November	86.0	68.5	74.6	91.4
December	85.0	68.5	76.4	88.2

Temperature and relative humidity at Ochoa, Costa Rica.

Month.	Temperature.			Relative humidity.
	Maximum.	Minimum.	Mean.	
1898.				
January	83.0	66.0	73.9	91.6
February	85.0	66.0	73.3	90.4
March	87.0	67.0	75.1	87.6
April	86.0	66.0	75.8	88.8
May	94.0	72.0	78.3	90.0
June	90.0	71.0	77.5	90.7
July	89.0	70.0	76.6	91.5
August	87.0	71.0	77.0	91.4
September	91.0	70.0	77.5	89.6
October	95.0	71.0	78.2	89.4
November	89.0	70.0	76.1	92.0
December	85.0	67.0	75.1	91.0
1899.				
January	84.5	67.0	74.8	93.2
February	86.0	68.0	75.3	91.9
March	91.0	67.0	75.6	89.7
April	88.5	68.0	76.6	87.0
May	89.5	70.0	77.9	90.6
June	86.0	72.0	77.7	90.2
July	85.5	72.5	77.3	92.6
August	96.0	71.5	77.5	92.2
September	90.0	72.0	78.4	89.8
October	88.5	72.5	79.0	89.0
November	87.0	72.0	77.4	91.4
December	84.5	68.0	75.1	92.6
1900.				
January	83.5	70.0	75.7	90.6
February	87.0	70.0	76.6	87.8
March	87.0	69.0	77.1	87.0
April	93.5	69.0	79.8	85.4
May	92.5	74.0	80.4	87.0
June	91.0	73.0	79.6	88.6
July	87.0	71.5	78.0	90.6
August	86.0	73.5	77.9	92.6
September	92.5	73.0	80.0	87.0
October	87.5	72.5	78.6	89.8
November	86.0	70.5	77.0	91.0
December	85.0	70.5	76.8	90.6

Temperature and relative humidity at San Juan del Norte, Nicaragua.

Month.	Temperature.			Relative humidity.
	Maximum.	Minimum.	Mean.	
1898.				
January	86	67	77.5	82.5
February	84	71	77.1	81.7
March	90	69	78.4	80.2
April	89	69	79.9	79.0
May	94	73	80.4	82.1
June	90	72	79.3	91.4
July	90	74	80.0	91.3
August	95	73	80.0	84.9
September	96	72	81.2	85.0
October	96	72	81.4	84.8
November	92	72	79.7	87.7
December	91	72	78.3	88.0
1899.				
January	86	69	77.8	87.3
February	88	66	77.2	87.7
March	90	72	79.7	80.9
April	92	70	80.6	78.0
May	98	72	81.0	84.0
June	89	74	79.5	85.4
July	88	73	78.7	86.2
August	88	72	78.0	87.4
September	90	73	79.3	86.6
October	88	72	80.3	84.2
November	88	73	78.2	88.6
December	85	70	76.0	88.2
1900.				
January	87	71	77.4	87.0
February	89	71	78.6	85.0
March	89	71	78.3	83.0
April	94	70	81.7	80.8
May	93	74	81.2	85.6
June	92	75	81.1	83.2
July	91	73	78.6	87.8
August	89	75	80.0	86.2
September	92	74	80.9	84.8
October	91	73	79.3	87.8
November	88	72	77.2	89.8
December	86	71	78.6	84.2

Monthly temperatures observed by the Panama Canal Company.

[In degrees Fahrenheit.]

Month.	La Boca.			Alhajuela.		
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
1899.						
July	91	70	78.8	88	72	79.7
August	88	68	75.0	94	71	80.0
September	91	69	77.0	97	72	80.6
October	86	70	76.4	94	71	78.8
November	88	69	76.8	91	72	79.5
December	89	68	77.9	91	66	78.9
1900.						
January	88	68	77.7	90	66	76.8
February	89	70	77.5	92	66	79.5
March	90	68	79.7	93	64	79.7
April	90	68	80.0	94	64	80.9
May	90	73	80.9	94	68	78.0
June	89	74	80.4	94	70	78.9
July	88	73	79.3	90	70	77.3
August	91	72	80.3	90	70	78.4
September	91	72	80.6	92	70	76.4
October	....	....	79.4	89	69	77.7
November	88	72	78.8	89	69	77.3
December	89	73	80.2	....	....	....
The year	91	68	79.6	....	....	....

The following two tables are taken from the reports of the United States Weather Bureau:

Temperature observations at Gamboa.

ABSOLUTE MAXIMUM TEMPERATURES.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1882	......	......	92.5	91.8	97.7	98.6	88.7	94.1	96.8	95.0	95.0	95.0	....
1883	......	......	......	......	......	......	......	......	......	......	......	......	....
1884	88.5	87.8	88.9	90.3	90.3	93.7	90.7	90.3	91.0	91.0	91.0	89.2	90.3
1885	88.2	88.9	90.3	94.3	97.5	95.4	91.4	88.9	93.6	93.9	92.1	91.0	92.1
1886	92.8	90.0	92.5	97.2	95.4	91.8	94.6	92.3	95.7	93.2	92.5	93.6	93.4
1887	91.4	90.0	92.8	91.8	96.4	93.6	93.0	91.4	91.8	93.9	93.2	91.8	92.3
Means	90.3	89.6	90.7	93.0	95.5	97.5	91.8	91.4	94.3	93.4	92.8	91.4	92.5

Temperature observations at Gamboa—Continued.

ABSOLUTE MINIMUM TEMPERATURES.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1882	......	......	62.6	53.6	63.0	59.0	71.6	66.2	66.2	66.6	64.4	......	......
1883	......	......	......	......	......	......	......	......	......	......	......	......	......
1884	60.4	59.0	58.6	61.2	65.8	66.6	68.0	65.8	66.9	65.8	66.2	59.0	63.7
1885	60.4	59.7	61.2	61.5	65.1	68.4	68.4	69.8	68.0	68.0	68.4	67.6	65.5
1886	58.6	60.4	61.5	65.5	68.0	68.4	66.9	68.7	67.6	60.8	67.6	63.0	64.8
1887	62.2	58.3	57.2	61.2	63.3	68.5	67.6	70.9	71.2	70.2	72.0	71.2	66.2
Means	60.4	59.4	60.8	60.6	65.1	66.2	68.5	68.4	68.0	66.2	67.6	65.3	64.8

MEAN TEMPERATURES.[a]

1882–1887	75.4	74.5	75.6	76.8	80.2	81.9	80.2	79.9	81.0	79.9	80.2	78.4	78.6

DEPARTURES OF THE MONTHLY MEANS FROM THE ANNUAL.

1882–1887	−3.2	−4.1	−3.0	−1.8	+1.6	+3.3	+1.6	+1.3	+2.4	+1.3	+1.6	−0.2	......

[a] Mean absolute maximum + mean absolute minimum ÷ 2.

Temperature observations at Colon.

ABSOLUTE MAXIMUM TEMPERATURES.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1882	85.3	87.1	84.9	87.8	88.7	88.5	88.2	89.6	91.8	92.1	88.9	89.2	88.5
1883	88.9	87.8	88.2	89.2	89.6	89.6	89.2	89.2	89.6	88.9	89.2	86.0	88.7
1884	86.4	85.6	86.4	87.8	89.6	89.6	90.7	91.4	90.5	91.2	95.9	92.1	89.8
1885	90.3	90.7	90.7	89.2	92.1	90.7	90.3	91.4	92.8	94.3	......	98.2	91.9
1886	98.2	92.8	98.2	96.8	93.9	93.9	93.2	93.9	93.9	96.1	95.7	94.6	95.2
1887	96.8	93.2	91.4	92.1	93.2	92.3	91.8	91.4	90.7	89.2	87.4	89.6	91.6
Means	90.9	89.6	90.0	90.5	91.2	90.9	90.5	91.2	91.6	91.9	91.4	91.6	90.9

ABSOLUTE MINIMUM TEMPERATURES.

1882	71.6	69.1	70.2	68.0	68.7	69.4	68.7	63.1	66.2	66.6	66.2	66.6	67.8
1883	68.0	70.5	64.4	65.5	69.4	68.0	68.4	66.2	69.8	68.4	63.7	66.9	66.5
1884	65.8	67.6	64.4	66.2	64.4	65.8	67.6	59.4	57.6	76.3	70.7	66.2	66.0
1885	71.2	66.9	72.7	70.2	72.0	70.5	71.6	70.2	70.5	71.2	71.2	70.2	70.7
1886	65.8	71.6	67.1	71.6	69.1	70.5	69.4	69.4	68.7	69.1	67.3	65.8	68.7
1887	67.6	69.4	66.6	69.1	68.0	70.3	70.5	73.0	74.5	72.3	73.8	73.4	70.7
Means	68.4	69.3	68.7	68.4	68.5	69.1	69.3	66.9	69.4	70.5	68.7	70.0	68.7

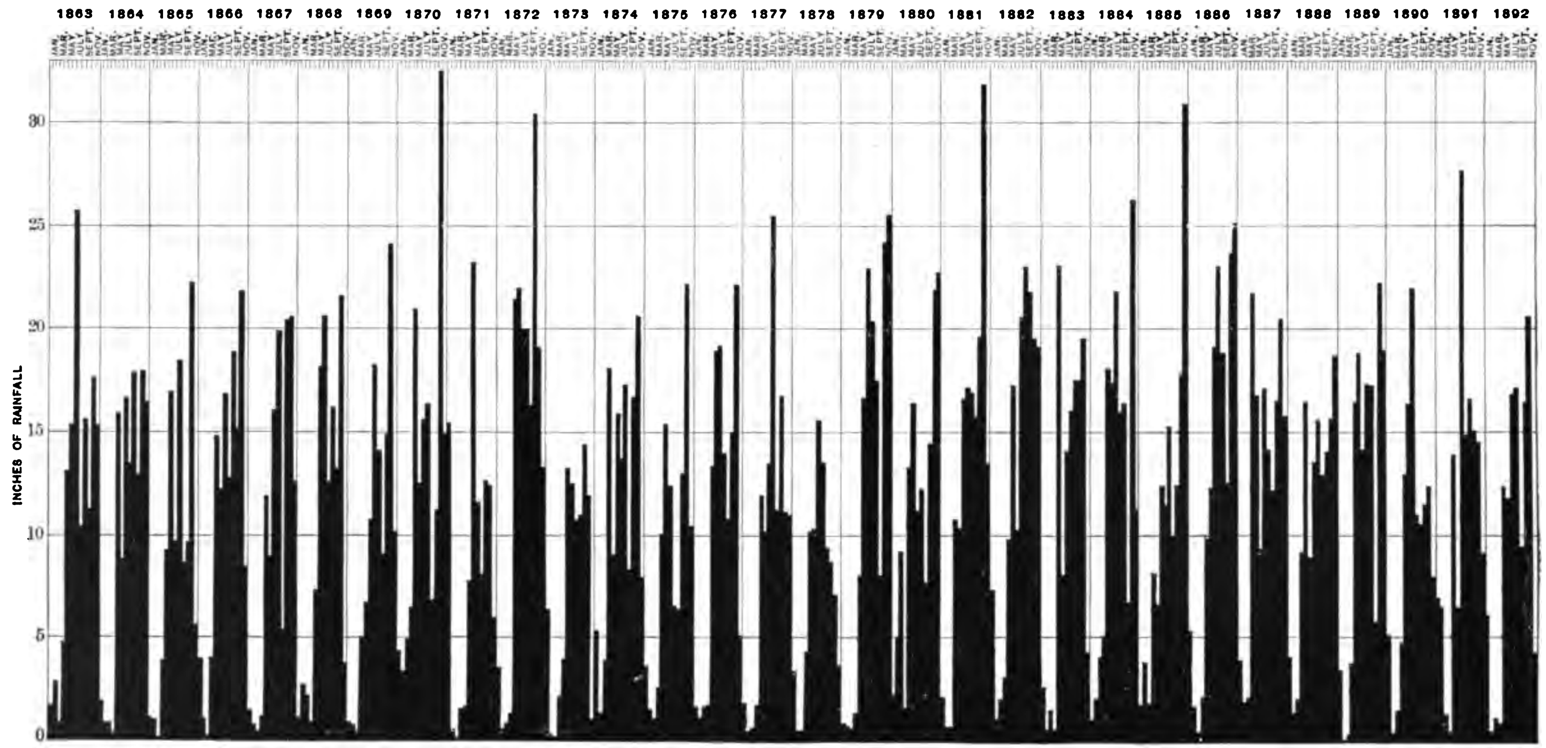
MEAN TEMPERATURES.[a]

1882–1887	79.5	79.5	79.3	79.5	79.9	79.9	79.9	79.2	80.6	81.3	80.1	79.9	79.9

DEPARTURES OF THE MONTHLY MEANS FROM THE ANNUAL.

1882–1887	−0.4	−0.4	−0.6	−0.4	0.0	0.0	0.0	−0.7	+0.7	+1.4	+0.2	0.0	......

[a] Mean absolute maximum + mean absolute minimum ÷ 2.



MONTHLY RAINFALL AT COLON, ON THE CARIBBEAN.

RAINFALL.

Considering the earth as a whole, no water can fall as rain except that which has previously been evaporated from its surface. The rainfall must, in the long run, therefore, be nearly equal to the evaporation, the temporary departures from such equality being due and equal to the fluctuating atmospheric humidity. The potential evaporation from the earth's surface varies from a few inches in polar regions to perhaps 100 inches in arid tropical localities, the mean being probably between 40 and 50 inches. But as about one-fourth of the earth's surface is land, upon which potential evaporation can not exercise its full possibilities for lack of water to evaporate, the average evaporation that actually takes place, and, hence, also, the mean rainfall of the world, is probably less than 40 inches.

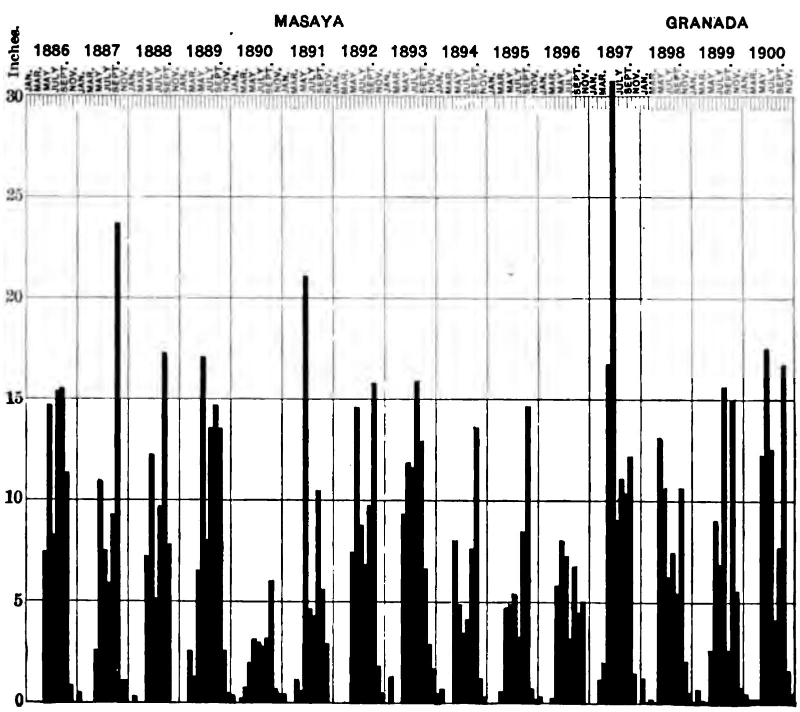


FIG. 227.—Monthly rainfall at Masaya and Granada, Nicaragua.

Considered by this standard, the greater part of Central America may be classed as a region of heavy rainfall, some of it excessively so. Although the Isthmus is narrow, the contrast between the two coasts is great, both as to the quantity and distribution of rainfall. On the Pacific side, where the greater part of the population is concentrated, the year is distinctly divided into two seasons—the wet and the dry—as distinctly defined and contrasting as strongly in rainfall as those seasons on the coast of California. There is some variation from year

to year in the dates of beginning and ending of these seasons, but the five months from December to April are dry, November and May are variable, and June to October are rainy months; the rainy season being usually a few weeks longer than the dry. In this region the annual precipitation varies from 30 to 90 inches, the mean being mostly between 50 and 60.

On the Caribbean side of the Isthmus the rainfall is greater and the dry season shorter and less definite. Here the relative humidity is uniformly high and no month in the year is entirely free from rain, though the months of February, March, and April are relatively dry months. These characteristics are shown on Pl. XXXVIII and fig. 227.

One of the most remarkable features of Isthmian climate is the limited region of excessive rainfall, of which the nucleus seems to be in the neighborhood of San Juan del Norte, Nicaragua. This is more fully discussed under heading "Hydrography of Nicaragua Canal route," page 546.

The general distribution of rain, so far as known, is shown in Pl. XXXIX.

The following tables give in condensed form some of the more important observations of rainfall on the Isthmus:

Annual rainfalls in Central America.

Year.	San Jose, Costa Rica.	Colon, Colombia.	Masaya, Nicaragua.	Granada, Nicaragua.	San Juan del Norte, Nicaragua.	San Antonio plantation, Nicaragua.	Bas Obispo, Panama.	Gamboa, Panama.	Bohio, Panama.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1863		134.31							
1864		123.43							
1865		106.14							
1866	63.93	129.71							
1867	73.47	[119.52]							
1868	56.09	120.03							
1869	62.92	114.78							
1870	75.09	149.64							
1871	75.56	99.58							
1872	86.78	168.50							
1873	55.84	87.12							
1874	60.83	137.70							
1875	59.76								
1876	50.43								
1877	53.42			61.34					
1878	60.29								
1879	86.37								
1880	61.50								
1881		[104.39]							
1882		124.10						77.29	
1883		115.34		47.43					
1884	19.49	86.54		35.98			74.71	94.59	
1885	69.60	146.29					81.23	97.48	
1886	154.30	137.17					91.00	102.87	

Annual rainfalls in Central America—Continued.

Year.	San Jose, Costa Rica.	Colon, Colombia.	Masaya, Nicaragua.	Granada, Nicaragua.	San Juan del Norte, Nicaragua.	San Antonio plantation, Nicaragua.	Bas Obispo, Panama.	Gamboa, Panama.	Bohio, Panama.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1887	71.48	154.88	61.22	....	....	....	98.27	136.19	....
1888	59.21	....	58.70	....	....	....	66.72	102.64	....
1889	85.18	....	78.78	....	....	....	77.53	75.72	....
1890	71.78	154.38	20.52	....	296.94	....	92.16	105.03	....
1891	65.18	124.73	49.98	....	214.27	....	83.82	77.67	....
1892	91.55	145.27	64.54	....	291.20	....	105.07	104.37	....
1893	97.90	131.89	72.86	....	....	....	123.00	117.81	....
1894	58.23	153.69	42.88	....	....	....	....	90.60	....
1895	76.75	151.54	41.26	....	....	69.83	....	....	....
1896	64.76	131.51	39.64	....	....	65.50	....	....	....
1897	74.97	138.03	....	93.62	....	98.26	....	107.91	181.65
1898	78.43	115.55	[50.73]	55.59	201.64	81.05	....	82.60	204.61
1899	....	183.02	45.24	56.93	285.93	67.22	....	80.00	118.98
1900	....	116.06	59.75	72.07	266.10	95.68	....	78.60	131.93
Mean.	70.70	129.25	54.20	60.42	259.35	79.59	89.26	87.28	159.29

Rainfall in Costa Rica previous to 1898.

[The stations in italic are on the Caribbean side of the main cordillera.]

	Longitude west of Greenwich.	Lat. N.	Altitude.	Years of observation.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
			Feet.		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Boca Banana	83° 01′ 51″	9° 56′	10	3	14.1	5.7	6.9	21.8	` 7.4	7.8	11.3	12.4	3.0	6.8	9.6	14.6	121.7
Port Limon	83° 03′	10° 00′	10	2	8.9	8.3	8.9	10.2	11.4	8.1	20.9	9.7	3.9	3.9	14.0	10.4	117.9
Matima	83° 22′	10° 06′	131	3	20.1	10.8	5.1	20.0	9.1	8.1	12.2	10.0	3.7	4.3	11.7	19.4	134.1
Jimenez	± 83° 48′	±10° 14′	820	1	18.0	5.3	8.8	11.2	16.6	10.2	8.1	15.4	7.2	17.9	9.4	25.0	153.1
Turrialba	± 83° 47′	± 9° 55′	2,110	5	9.1	2.1	3.1	10.6	9.4	12.4	9.1	10.0	10.0	9.4	7.5	17.8	110.6
Tuis	± 83° 38′	± 9° 51′	2,133	2	6.7	3.7	2.1	10.5	12.0	10.6	9.3	5.9	10.9	7.9	7.8	18.5	105.9
Juan Viñas	± 83° 45′	± 9° 55′	3,740	2½	13.1	3.3	4.6	5.0	7.2	7.5	6.6	8.7	7.3	7.9	6.8	14.0	91.7
Cartago	± 83° 55′	± 9° 55′	4,842	3	3.7	1.7	1.0	2.7	7.1	5.1	3.2	6.3	7.2	11.1	3.5	3.4	56.0
Aguacaliente	± 83° 57′	± 9° 55′	4,475	2	1.7	0.4	1.4	1.6	7.5	5.3	4.3	7.4	7.2	10.5	1.4	6.0	54.7
Tres Rios	± 83° 57′	± 9° 56′	4,265	7	0.4	0.0	0.2	2.9	1.4	10.3	6.7	9.7	13.2	17.2	6.7	2.0	83.6
La Verbena	± 84° 04′	± 9° 55′	3,740	2	0.0	0.0	1.0	2.3	14.0	14.3	7.4	9.1	12.5	14.7	7.4	1.9	84.3
San Jose	84° 03′	9° 56′	3,806	30	0.6	0.1	0.7	1.8	8.8	9.3	8.2	9.5	12.5	11.8	5.9	1.5	70.7
San Francisco	± 84° 03′	± 9° 57′	3,937	3	1.0	0.0	0.4	2.9	9.4	10.8	7.3	11.1	11.2	12.0	6.9	1.3	74.2
Heredia	± 84° 09′	± 9° 59′	3,871	3	1.6	0.3	0.0	0.8	2.2	8.9	8.7	5.7	5.4	9.2	14.1	4.·1	61.2
La Palma, on the divide	± 83° 59′	±10° 03′	4,790	2	18.5	3.0	2.7	7.4	10.0	16.9	11.3	10.6	9.2	9.8	11.0	24.9	134.8
San Carlos	± 84° 31′	±10° 24′	164	½	7.7	......	......	......	......	......	......	13.0	13.2	13.4	15.3	6.1	......

Monthly rainfall in Costa Rica, 1898 to 1900.

1898.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Boca Banana	18.74	5.20	7.87	8.43	10.12	7.52	8.98	4.49	1.38	3.74	8.86	7.05	92.38
Limon	......	2.16	11.37	9.35	15.55	6.89	7.76	......	1.41	2.99	13.62	6.22	......
Swamp Mouth	......	......	......	13.58	8.82	6.65	12.44	5.11	1.38	......	......	......	......
Gute Hoffnung	27.32	7.68	6.61	7.91	7.87	11.49	10.83	1.29	1.88	2.51	12.67	9.06	107.12
Rio Honda	34.25	7.68	6.89	8.97	......	......	10.98	8.82	4.48	4.48	10.15	......	......
Siquirres	21.06	11.18	6.54	12.04	9.88	11.81	9.13	7.95	......	5.43	......	4.13	......
Peralta	......	......	......	8.22	15.90	21.96	9.96	10.0	8.74	6.02	9.84	6.81	......
Turrialba	10.23	2.4	5.43	7.32	7.99	15.98	5.67	4.72	9.72	7.36	8.03	3.89	88.74
Juan Vinas	7.87	2.0	7.52	5.75	6.89	7.83	8.39	8.27	8.98	8.98	7.09	3.66	83.26
San Rafael de Cartago	3.11	1.25	0.82	1.14	8.19	9.47	4.41	7.56	1.38	13.42	3.42	0.47	67.06
San Diego	0.47	......	0.11	1.65	7.79	13.07	6.11	11.96	21.18	15.74	7.05	......	......
La Palma	17.71	5.89	5.39	6.77	9.88	17.79	9.02	9.92	......	......	......	......	......
San Francisco Guadalupe	1.43	......	0.27	1.14	9.61	16.02	7.68	11.57	15.27	12.08	5.28	0.078	79.428
San Jose	0.35	......	0.27	9.61	8.58	15.59	8.92	13.42	13.62	11.69	4.65	0.078	86.778
Hacienda La Verbena	......	......	......	......	......	......	13.3	12.12	15.70	24.05	10.35	......	......
Sarapiqui coffee estates	......	......	......	......	......	......	16.81	17.48	19.4	19.28	21.73	5.16	......
Nuestro Amo	......	......	......	......	......	11.57	5.24	11.80	14.92	8.15	5.19	......	......
San Carlos	......	......	......	......	......	......	......	13.03	13.22	13.42	15.27	6.14	......
1899.	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**June.**	**July.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Total.**
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Boca Banana	12.91	15.55	5.55	8.74	9.29	6.57	25.00	11.68	6.81	1.33	12.37	12.36	128.16
Limon	......	......	5.28	8.03	14.52	......	29.29	......	......	3.93	11.22	13.14	......
Swamp Mouth	12.00	8.62	8.62	4.65	......	......	......	......	......	......	......	......	......
Gute Hoffnung	10.11	12.87	5.08	5.87	4.76	6.11	22.36	6.49	4.13	5.51	14.64	14.13	112.06
Peralta	8.61	7.72	3.34	6.02	......	......	......	......	7.05	7.58	9.69	10.19	......
Aragon	8.39	4.17	3.42	......	......	......	......	......	......	......	......	......	......
Juan Vinas	6.54	3.77	2.04	4.76	5.47	4.69	16.73	6.97	4.76	8.89	7.56	13.81	85.99
San Rafael de Cartago	......	......	......	......	......	5.24	9.92	3.22	2.32	7.28	8.74	......	......
San Diego	0.86	0.66	0.23	1.18	1.92	10.19	12.12	6.61	4.57	15.51	8.19	0.157	62.191
San Francisco Guadalupe	1.57	0.31	1.57	1.81	2.55	9.13	14.44	6.81	6.65	7.59	7.36	0.196	59.86
San Jose	1.69	0.196	1.45	1.25	2.55	8.35	15.86	0.392	......	......	......	......	......
Hacienda La Verbena	1.37	0.55	0.86	0.089	1.96	8.26	13.81	6.61	6.69	7.36	8.19	0.196	55.895
Nuestro Amo	......	......	......	0.66	4.25	8.66	7.68	6.06	7.44	11.41	8.31	......	......
Sarapiqui	8.43	12.36	3.22	5.24	15.47	18.54	22.75	16.61	9.96	22.83	24.76	20.03	180.20
San Carlos	7.72	10.74	1.81	4.13	12.24	11.73	22.83	9.88	9.72	15.94	20.86	15.03	142.63

Monthly rainfall in Costa Rica, 1898 to 1900—Continued.

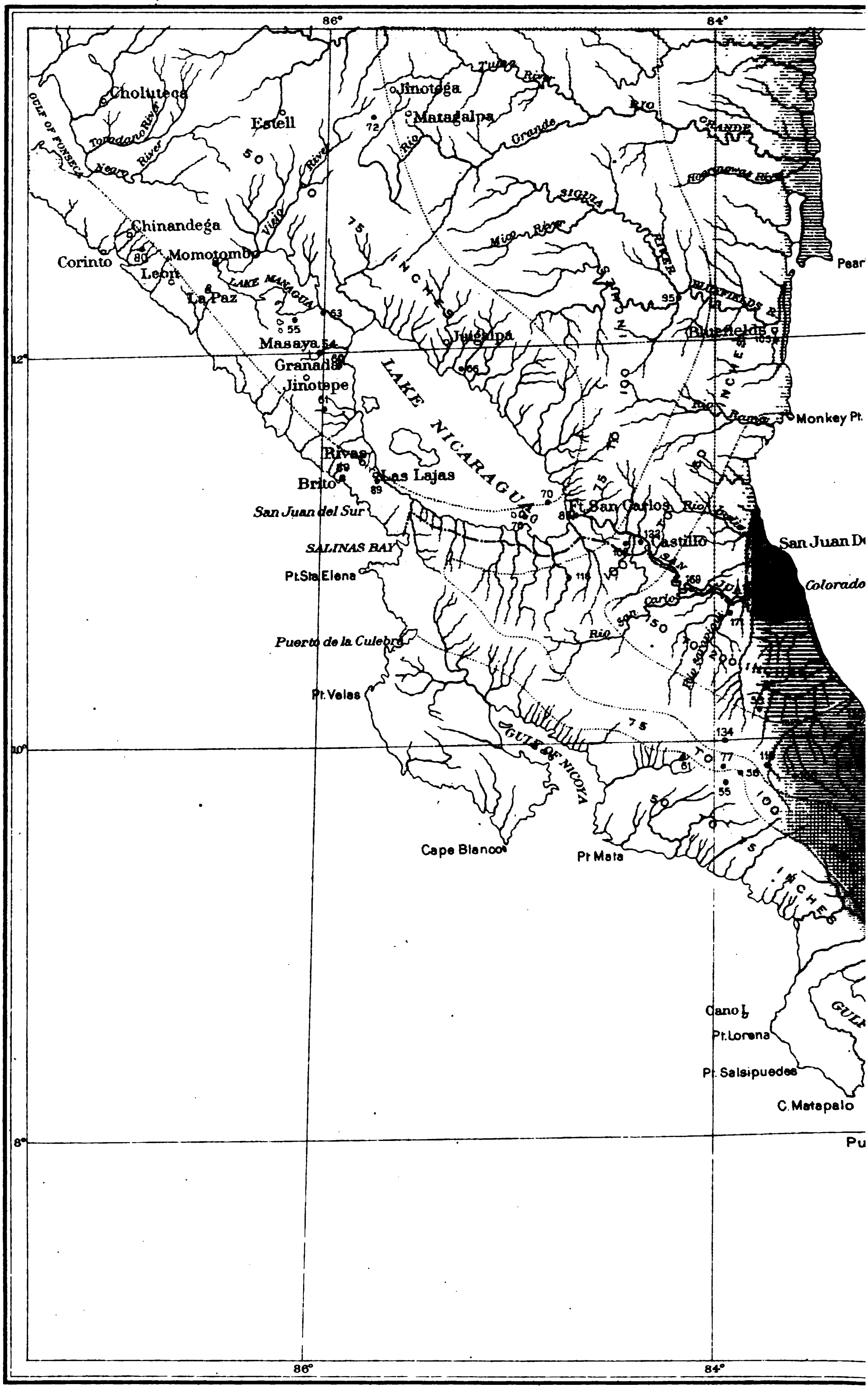
1900.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Boca Banana	6.65	4.84	9.84	9.88	5.12	2.87	7.1	21.6	8.98	6.18	9.72	12.16	104.94
Limon	......	8.3	9.57	10.27	3.58	3.82	8.27	......	10.9	3.98	8.07	13.74	......
Swamp Mouth	......	......	......	......	......	......	......	......	9.41	2.6	......	12.63	......
Gute Hoffnung	4.57	4.61	9.09	12.16	8.19	4.57	10.19	26.26	9.84	10.31	11.78	10.67	122.19
Siquirres	......	......	9.61	9.57	......	9.25	......	18.3	7.85	8.82	0.23	9.53	......
Guapiles	......	......	......	......	......	......	4.61	30.9	16.1	......	25.6	14.56	......
Las Lomas	......	......	......	......	......	......	......	15.9	11.37	13.22	19.96	14.4	......
Peralta	4.49	1.9	7.05	9.25	21.53	13.58	13.11	13.81	14.64	16.26	11.77	14.4	141.79
Juan Vinas	2.48	3.66	......	......	......	......	......	......	......	......	......	7.52	......
San Diego	0.19	......	0.11	2.59	14.64	13.34	15.43	3.48	12.12	11.53	6.77	0.66	80.86
San Francisco Guadalupe	0.078	......	0.55	2.55	7.01	19.25	14.13	3.31	10.75	17.32	6.34	0.51	81.789
San Jose	0.039	......	0.82	2.76	6.98	19.88	15.59	3.11	10.23	16.29	6.54	1.1	83.289
Hacienda la Verbena	......	......	0.29	0.94	8.62	14.08	8.78	3.74	12.08	16.22	5.87	......	70.62
Nuestro Amo	......	......	3.85	1.25	11.1	12.67	16.33	3.42	12.4	22.12	7.95	......	91.09
Alajuela	......	......	......	......	......	......	......	......	11.53	24.13	9.45	......	......
Sarapiqui	8.31	8.31	4.02	10.55	20.35	25.35	22.75	8.86	15.7	27.75	27.4	11.81	191.16
San Carlos	8.03	3.78	3.11	5.43	14.96	7.95	17.12	13.5	12.87	19.88	21.69	10.23	138.55

WIND MOVEMENT.

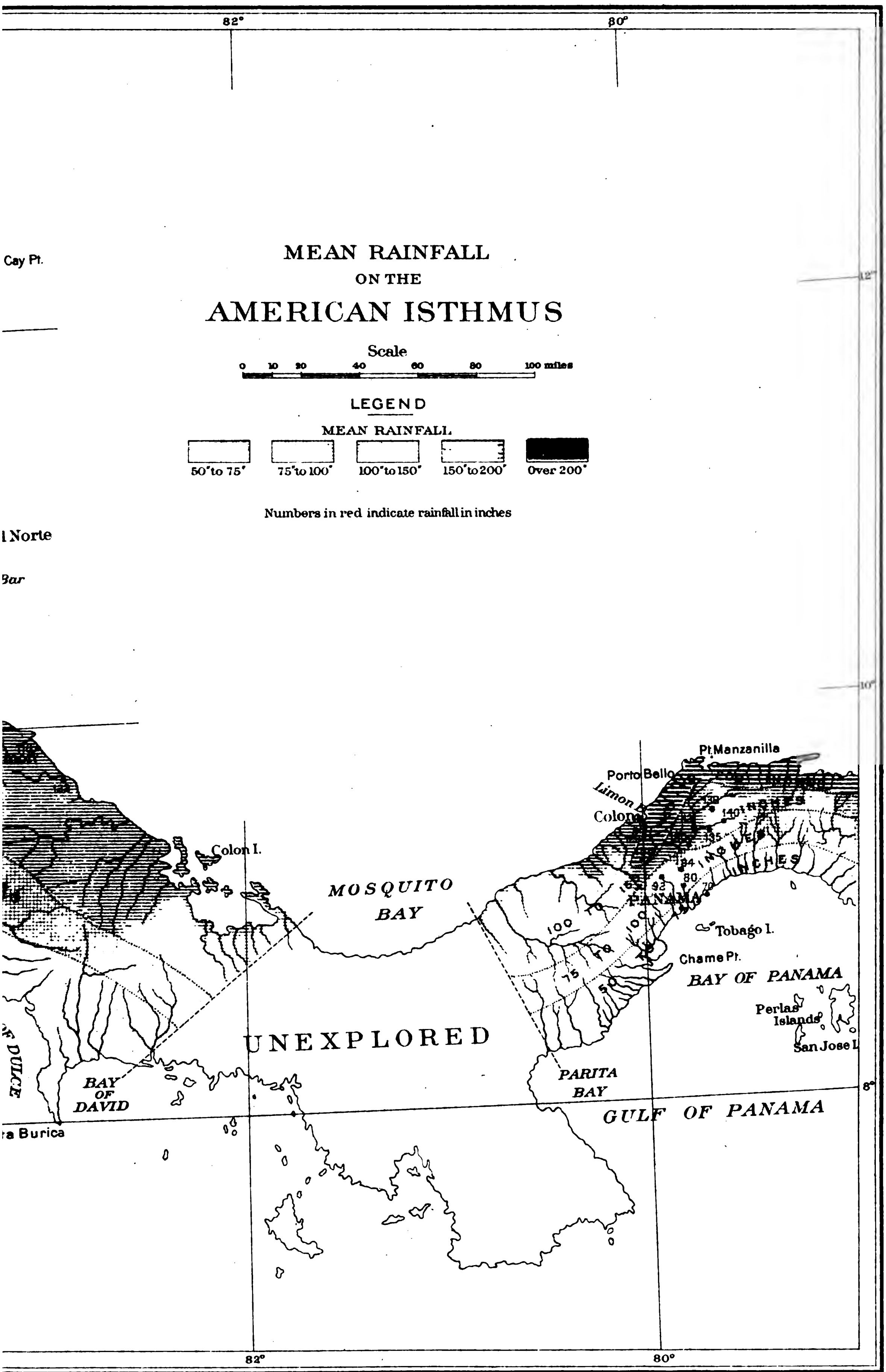
One point of interest in the consideration of the Isthmian canal is the strength and persistence of winds, considered as motive force for sailing vessels, and as annoyance to the navigation of the canal and to ships entering and leaving port.

The persistence of the trade winds has frequently been mentioned in discussions of the Nicaragua Canal route. In 1898, it being necessary to take gage readings at Las Lajas, on the western margin of the lake, for transferring the level line across the lake, a camp with an observer was established here and the gage height of the lake was observed at 6 and 9 a. m., 12 noon, 3 and 6 p. m. Note of the condition of the lake surface was made at each observation, and from January 19, 1898, when the observations began, until the 1st of May a heavy surf was beating on the beach at this point at every observation, due to the persistence of the trade winds. A few days of calm occurred in May and at later periods during the rainy season.

On May 16, 1900, an anemometer was installed at San Juan del Norte and observed at 8 a. m., 12 noon, and 6 p. m. each day, and the record was kept practically continuous to the end of the year. In all this time not a single day occurred without wind movement; the highest velocity recorded being something over 40 miles per hour, and this occurred on only one day, November 13. The mean for that day was 24.5.



86°
84°
Choluteca
Estell
Jinotega
Matagalpa
Tuma River
Rio Grande
GULF OF FONSECA
Tondano River
Negro River
Viejo River
Chinandega
Corinto
Momotombo
Leon
La Paz
LAKE MANAGUA
Masaya
Granada
Jinotepe
Juigalpa
Mico River
SIQUIA
Bluefields
Pear
Monkey Pt.
Rio Rama
LAKE NICARAGUA
Rivas
Brito
Las Lajas
San Juan del Sur
SALINAS BAY
Pt.Sta Elena
Ft.San Carlos
Castillo
San Juan D
Colorado
Rio San Carlos
Puerto de la Culebra
Pt.Velas
GULF OF NICOYA
Cape Blanco
Pt Mata
Cano I.
Pt.Lorena
Pt. Salsipuedes
C.Matapalo
Pu
12°
10°
8°
50
75 INCHES
100 INCHES
150



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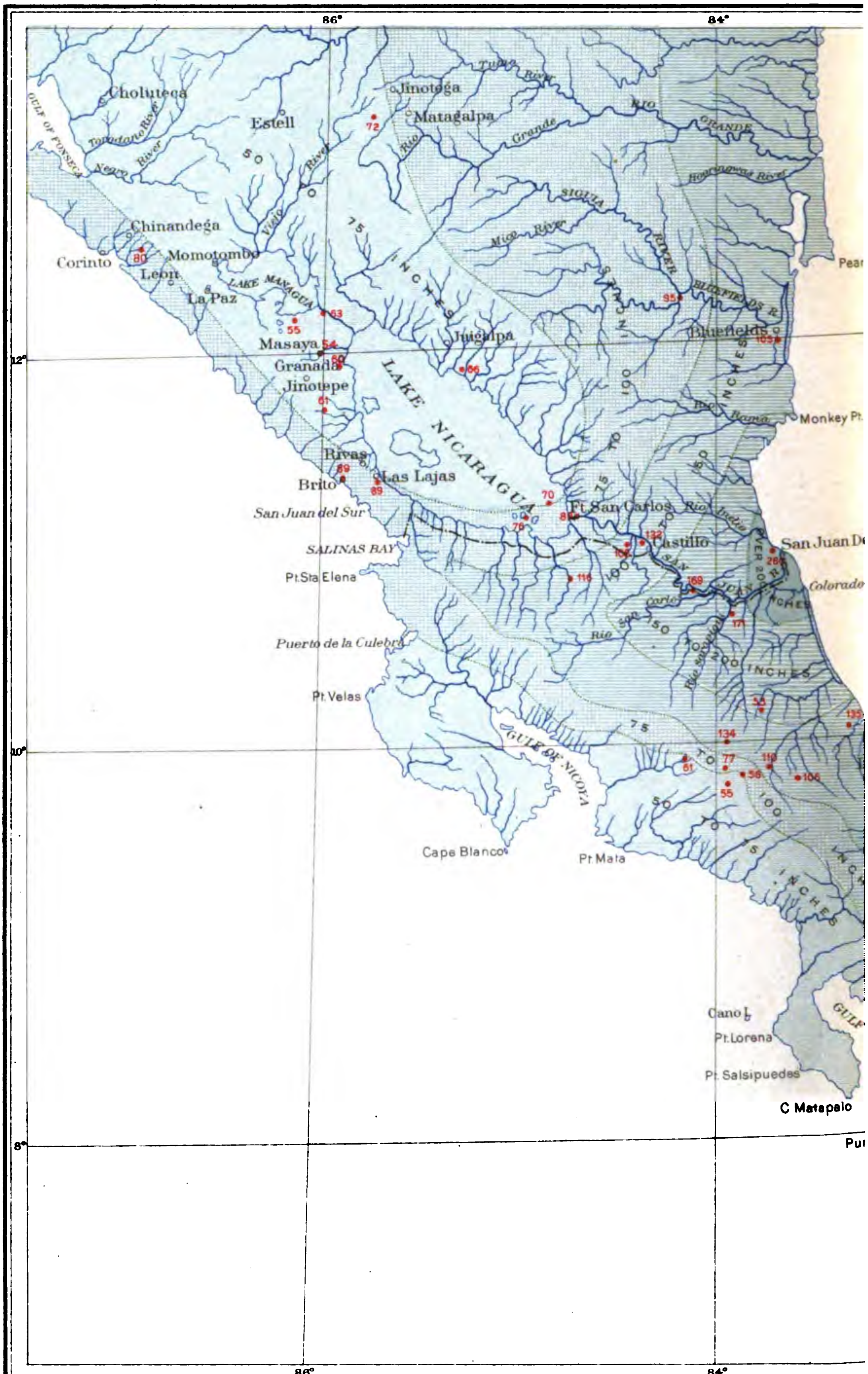
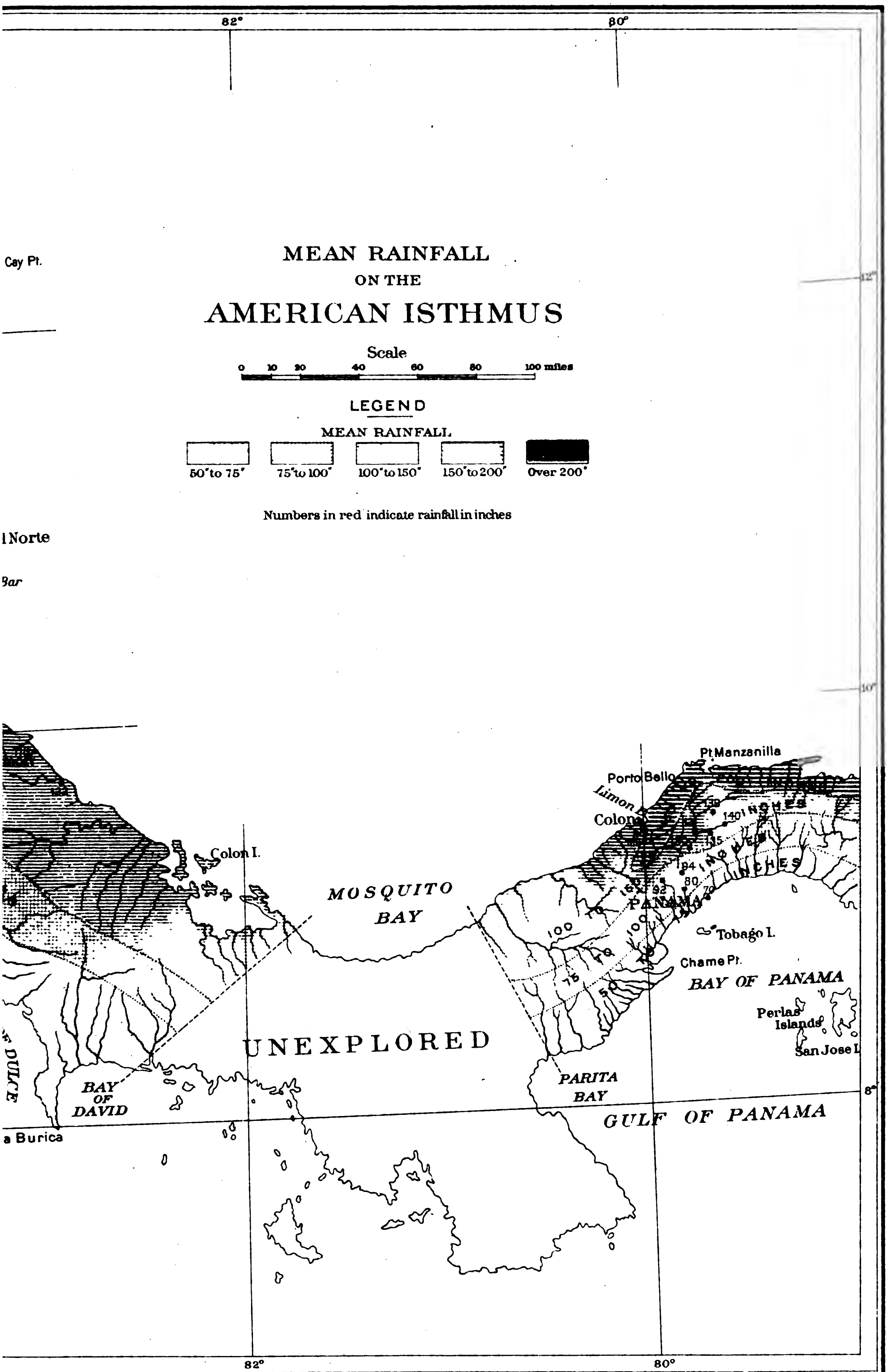

86°
84°
12°
10°
8°
Choluteca
Estell
Jinotega
Matagalpa
Chinandega
Corinto
Momotombo
Leon
La Paz
LAKE MANAGUA
Masaya
Granada
Jinotepe
Juigalpa
LAKE NICARAGUA
Rivas
Brito
Las Lajas
San Juan del Sur
SALINAS BAY
Pt. Sta Elena
Puerto de la Culebra
Pt. Velas
GULF OF NICOYA
Cape Blanco
Pt. Mata
Ft. San Carlos
Castillo
San Juan De
Colorado
Bluefields
BLUEFIELDS R.
Monkey Pt.
Rio Rama
SIGUIA RIVER
Mico River
RIO GRANDE
Tuma River
Rio Grande
GULF OF FONSECA
Negro River
Viejo River
Rio San Carlos
Rio Sarapiqui
C Matapalo
Pt. Lorena
Pt. Salsipuedes
Cano I.
50 INCHES
75 INCHES
100 INCHES
150 INCHES
200 INCHES
72
80
63
55
54
60
61
66
95
103
69
89
70
70
88
132
166
116
169
268
171
134
77
110
56
55
106
135
53
61



JULIUS BIEN & CO. LITH. N.Y.

The results of the observations are shown in the following table:

Anemometer record at San Juan del Norte, Nicaragua.

Day.	May.					June.				
	Anemometer readings.			Miles.		Anemometer readings.			Miles.	
	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.
1	....	....	....	....	....	677.4	786.1	754.5	127.4	5.3
2	....	....	....	....	....	804.5	922.9	980.9	121.8	5.1
3	....	....	....	....	....	926.3	950.8	3.2	118.8	4.5
4	....	....	....	....	....	45.1	81.5	100.4	154.9	6.5
5	....	....	....	....	....	200.0	222.8	278.9	195.7	8.2
6	....	....	....	....	....	395.7	413.5	431.0	94.5	3.5
7	....	....	....	....	....	490.2	525.0	562.4	133.5	5.6
8	....	....	....	....	....	623.7	659.1	694.0	106.3	4.4
9	....	....	....	....	....	730.0	754.0	801.0	102.1	4.3
10	....	....	....	....	....	832.1	835.0	842.5	99.4	4.2
11	....	....	....	....	....	931.5	973.1	19.0	123.8	5.1
12	....	....	....	....	....	55.3	111.0	133.0	114.7	4.9
13	....	....	....	....	....	170.0	193.2	221.5	81.0	3.4
14	....	....	....	....	....	251.0	283.0	315.2	101.1	4.2
15	....	....	....	....	....	352.1	370.7	416.3	97.7	4.1
16	78.0	93.6	117.2	68.7	2.9	449.8	473.1	499.0	75.8	3.2
17	146.7	178.0	212.1	99.4	4.1	525.6	554.1	569.0	78.4	3.3
18	246.1	271.0	313.6	127.1	5.3	604.0	620.2	653.6	128.0	5.3
19	373.2	399.0	403.3	62.3	2.6	732.0	751.6	784.1	93.7	3.9
20	435.5	450.3	497.5	97.6	4.1	825.7	837.2	855.2	79.3	3.3
21	533.1	553.4	589.0	85.2	3.6	905.0	832.0	953.2	82.1	3.4
22	618.3	639.3	688.6	105.0	4.4	987.1	10.7	45.2	78.7	3.3
23	723.3	755.5	801.2	99.9	4.2	65.8	81.2	186.7	146.3	6.1
24	823.2	869.0	916.1	119.8	5.0	212.1	237.3	307.2	117.0	4.8
25	943.0	984.1	41.7	139.5	5.8	329.1	343.3	378.8	72.5	3.0
26	82.5	95.5	130.9	91.1	3.8	401.6	419.1	470.0	98.4	4.1
27	173.6	195.2	226.0	115.2	4.8	500.0	515.5	567.2	103.0	4.3
28	288.8	317.8	353.5	129.8	5.8	603.0	624.2	664.0	129.0	5.4
29	418.6	438.8	467.7	84.7	3.5	732.0	744.2	822.5	147.0	6.1
30	503.3	521.1	549.1	101.7	4.2	879.0	897.6	967.0	155.1	6.5
31	605.0	626.2	652.1	72.4	3.0	....	....	....	....	....

Anemometer record at San Juan del Norte, Nicaragua—Continued.

Day.	July.					August.				
	Anemometer readings.			Miles.		Anemometer readings.			Miles.	
	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.
1	34.1	50.0	69.1	77.8	3.2	200.0	215.8	250.0	127.2	5.3
2	111.9	152.2	172.4	97.1	4.1	327.2	339.3	381.2	93.8	3.9
3	209.0	219.1	235.8	54.2	2.3	421.0	433.6	552.7	230.5	9.6
4	263 2	281.0	328.4	113.9	4.7	651.5	663.7	700.0	71.6	3.0
5	377.1	397.4	463.5	140.9	5.9	723.1	732.4	778.3	85.9	3.6
6	518.0	532.1	568.9	99.0	4.2	809.0	838.7	874.0	104.2	4.4
7	617.0	625.1	683.1	167.8	7.0	913.2	924.2	950.0	86.8	3.6
8	784.8	806.1	843.2	88.4	3.7	1,000.0	9.2	29.0	120.7	5.0
9	873.2	890.5	920.1	94.8	3.9	120.7	141.9	196.0	119.5	5.0
10	968.0	995.2	62.5	102.0	4.3	240.2	252.1	284.8	148.8	6.2
11	70.0	83.2	105.2	58.1	2.4	389.0	415.0	487.6	215.5	8.9
12	128.1	140.2	169.7	85.7	3.6	604.5	612.0	625.2	74.2	3.1
13	213.8	230.0	275.5	96.3	4.1	678.7	700.2	734.5	48.0	2.0
14	310.1	349.2	395.0	153.9	6.5	726.7	820.0	867.5	216.7	9.0
15	464.0	478.0	502.5	108.2	4.5	943.4	975.0	32.5	118.9	4.9
16	572.2	590.0	664.5	145.8	6.1	62.3	79.6	116.1	93.3	3.9
17	718.0	733.0	761.5	102.2	4.3	155.6	182.8	246.8	141.4	5.9
18	820.2	860.1	895.0	142.8	5.9	297.0	312.4	349.5	101.1	4.2
19	963.0	991.5	47.0	121.6	5.1	398.1	416.2	446.7	97.1	4.0
20	84.6	91.2	116.0	62.5	2.6	495.2	506.4	549.0	102.1	4.3
21	147.1	166.5	182.3	84.4	3.5	597.3	646.6	680.0	102.0	4.2
22	231.5	246.2	276.0	73.6	3.1	699.3	718.7	743.2	75.8	3.2
23	305.1	330.0	363.2	83.4	3.5	775.1	787.4	818.1	78.6	3.3
24	388.5	406.5	438.0	83.5	3.5	853.7	877.4	944.2	138.6	5.8
25	472.0	490.1	543.2	107.0	4.4	992.3	18.7	65.5	114.3	4.3
26	579.0	602.1	650.8	134.0	5.6	106.6	117.8	141.2	84.2	3.5
27	713.0	725.8	758.0	81.0	3.4	190.8	214.6	261.0	137.2	5.7
28	794.0	836.0	889.2	135.0	5.6	328.0	346.2	409.0	138.1	5.8
29	929.0	941.3	994.0	84.5	3.5	466.1	424.5	511.9	74.9	3.2
30	13.5	24.1	55.2	76.0	3.2	541.0	552.7	536.2	140.0	5.8
31	89.5	102.3	156.2	110.5	4.0	681.0	698.3	739.6	87.4	3.6

Anemometer record at San Juan del Norte, Nicaragua—Continued.

Day.	September.					October.				
	Anemometer readings.			Miles.		Anemometer readings.			Miles.	
	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.
1	768.4	782.0	799.3	70.7	2.9	127.8	162.2	203.7	108.5	4.5
2	839.1	848.3	890.1	81.4	3.4	236.3	251.2	300.0	96.7	4.0
3	920.5	947.2	999.0	79.5	3.3	333.0	347.1	406.4	114.2	4.3
4	1000.0	19.9	76.5	102.0	4.3	447.2	472.3	557.9	150.9	6.3
5	102.0	120.2	163.8	97.2	4.1	598.1	623.0	693.2	131.2	5.4
6	199.2	211.1	250.4	108.2	4.5	729.3	747.8	795.9	101.8	4.2
7	307.4	326.4	369.0	89.6	3.7	831.1	846.2	880.0	70.1	2.9
8	397.0	411.5	461.0	89.7	3.8	901.2	923.6	1000.0	130.1	5.4
9	486.7	507.2	553.6	114.7	4.8	31.3	57.6	111.1	85.8	3.6
10	601.4	621.0	673.1	99.9	4.2	117.1	122.5	202.6	111.9	4.7
11	701.3	719.5	763.3	101.8	4.2	229.0	246.4	273.1	69.4	2.9
12	803.1	815.7	845.0	57.6	2.4	298.4	316.2	359.6	87.6	3.6
13	860.7	873.4	911.6	81.0	3.4	386.0	399.4	427.1	52.6	2.2
14	941.7	953.1	1000.0	95.5	4.0	438.6	463.1	556.9	152.5	6.4
15	37.2	52.1	102.3	109.5	4.5	591.1	608.7	648.6	87.9	3.6
16	146.7	160.5	223.2	145.5	6.1	679.0	699.3	753.2	118.3	4.9
17	292.2	321.6	401.3	159.8	6.6	797.3	812.5	860.0	104.7	4.4
18	452.0	472.1	501.3	71.0	3.0	902.0	912.3	995.1	115.3	4.8
19	523.0	540.8	601.2	91.2	3.8	17.3	38.2	76.1	92.0	3.8
20	614.2	632.4	681.1	150.9	6.3	109.[illegible]	125.2	198.6	107.8	4.5
21	765.1	783.9	830.5	119.6	5.0	217.1	232.0	275.4	104.0	4.3
22	884.7	899.0	948.9	111.3	4.6	321.1	339.2	381.2	122.2	5.1
23	996.0	15.6	49.5	86.3	3.6	443.3	477.0	488.2	51.4	2.1
24	82.3	100.2	161.1	1 9.2	6.2	494.7	516.2	578.3	117.3	4.9
25	231.5	243.5	299.4	105.9	4.4	612.0	650.0	700.3	157.4	6.6
26	837.4	861.2	433.1	197.3	8.2	769.4	805.1	867.4	....	......
27	584.7	553.1	612.2	140.8	5.9					
28	675.5	693.3	759.1	125.8	5.2	(a)	....	....	....	......
29	801.3	824.4	900.0	184.7	7.7					
30	986.0	20.1	97.3	141.8	5.9					

[a] No record.

Anemometer record at San Juan del Norte, Nicaragua—Continued.

Day.	November.					December.				
	Anemometer readings.			Miles.		Anemometer readings.			Miles.	
	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.
1	319.5	326.1	515.2	255.0	10.6	610.5	674.2	760.1	....	....
2	574.5	593.0	631.9	119.2	5.0	....	....	....	....	....
3	693.7	716.5	694.0	113.6	4.7	835.1	866.4	902.8	128.3	5.3
4	807.3	912.0	980.9	201.4	8.4	963.4	21.0	49.2	143.4	16.0
5	8.7	25.8	125.6	84.2	3.5	106.8	150.1	187.6	155.2	6.5
6	92.9	74.5	118.2	....	....	261.0	296.5	330.0	249.0	10.4
7	....	....	....	....	....	510.0	646.3	741.0	288.4	12.0
8	453.0	403.0	480.5	210.6	8.8	798.4	824.0	866.2	95.6	4.0
9	663.6	694.0	747.8	197.1	8.2	894.0	976.5	997.0	198.3	8.3
10	860.7	907.1	955.2	236.4	9.9	92.3	141.6	188.9	117.2	4.9
11	97.1	145.3	136.6	148.9	6.2	209.5	261.2	278.6	85.2	3.6
12	246.0	234.6	227.9	178.2	7.4	294.7	312.1	329.6	106.5	4.4
13	424.2	608.5	870.0	588.6	24.5	401.2	419.5	439.2	64.9	2.7
14	12.8	81.1	87.4	71.5	3.0	466.1	484.6	504.9	70.0	2.9
15	84.3	94.7	135.7	210.4	8.8	536.1	581.2	601.4	95.4	4.0
16	294.7	213.6	355.2	63.9	2.7	631.5	649.0	684.0	130.3	5.4
17	358.6	411.0	428.2	79.3	3.8	761.8	794.0	822.6	132.2	5.5
18	437.9	490.4	499.0	125.1	5.3	894.0	931.4	962.0	103.1	4.3
19	563.0	592.8	640.7	139.5	5.8	997.1	42.4	87.6	145.8	6.1
20	702.5	740.6	794.3	157.6	6.6	142.9	186.1	241.0	153.4	6.4
21	860.1	878.0	921.6	78.8	3.3	296.3	361.2	398.0	183.9	7.7
22	938.9	963.4	986.0	55.3	2.3	480.2	511.2	531.4	118.4	4.9
23	994.2	14.8	132.5	196.8	8.3	598.6	623.9	641.7	94.4	3.9
24	191.0	214.6	384.0	313.2	13.0	693.0	768.2	802.0	167.1	7.0
25	504.2	524.0	557.7	116.7	4.9	860.1	....	....	....	....
26	620.9	769.8	798.3	199.5	8.3	....	978.0	61.7	....	....
27	820.4	846.2	910.1	115.8	4.8	92.8	111.4	137.5	75.4	3.1
28	936.2	958.7	971.6	55.8	2.3	168.2	179.0	194.7	53.2	2.2
29	992.0	210.5	401.6	466.6	19.4	221.4	236.0	252.3	68.2	2.8
30	458.6	521.4	539.0	151.9	6.3	289.6	302.5	319.8	48.6	2.0
31	....	....	....	....	....	338.2	356.4	379.6	74.2	3.1

Observations of wind velocity at Ochoa station for 1899.

[Representing estimated mean velocity of wind, in miles per hour, for daytime only.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7	3	5	8	3	4	8	7	3	4	3	3
2	16	8	3	13	5	3	5	2	4	3	3	0
3	11	3	3	7	3	5	5	7	3	5	0	3
4	7	13	5	7	3	5	8	0	3	4	0	3
5	5	8	5	8	5	3	8	3	4	4	3	......
6	5	7	5	5	3	8	3	3	4	3	0	......
7	8	7	13	5	5	5	8	4	5	7	3	......
8	3	8	13	1	8	3	3	0	5	5	3	0
9	3	8	13	3	11	2	0	0	7	3	5	0
10	3	3	13	5	11	0	0	5	5	5	0	5
11	0	3	11	5	5	1	0	5	3	3	3	4
12	3	5	5	3	5	1	3	4	3	5	8	3
13	7	13	8	3	13	3	0	4	4	7	0	8
14	3	5	7	5	23	3	0	4	4	4	18	7
15	8	3	3	5	5	5	3	0	5	3	13	8
16	5	3	11	7	13	5	5	3	0	5	3	11
17	0	5	13	8	3	8	8	5	8	5	0	5
18	0	3	8	5	22	0	3	0	3	8	3	0
19	4	8	8	5	0	3	4	7	7	3	4	8
20	3	5	5	8	5	3	7	5	1	3	4	8
21	8	11	3	8	3	7	2	3	0	7	5	7
22	8	11	5	8	10	8	3	5	0	13	4	9
23	5	5	5	8	13	8	0	4	3	0	3	18
24	7	4	5	13	0	3	13	5	0	3	1	0
25	5	7	8	8	0	0	......	8	3	13	0	7
26	7	5	8	8	13	0	......	3	5	7	5	38
27	3	8	5	8	22	5	3	1	0	7	0	0
28	5	8	4	8	4	5	3	4	0	4	5	18
29	8	......	5	8	3	8	8	3	3	3	0	7
30	8	......	8	5	5	5	7	1	3	0	0	4
31	3	......	5	......	3	......	5	0	......	3	......	7

Observations of wind velocity at Ochoa station in 1900.

[Representing estimated mean velocity of wind, in miles per hour, for daytime only.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7	8	7	7	8	8	0	0	0	0	28	3
2	11	7	0	13	7	5	4	0	1	0	0	3
3	7	5	8	13	0	8	0	0	3	7	5	3
4	3	7	18	5	13	5	4	0	4	7	0	3
5	0	5	4	13	8	0	0	3	0	5	4	4
6	8	13	18	13	0	5	8	0	3	8	5	3
7	7	3	13	3	8	4	4	3	5	13	0	3
8	7	13	13	8	0	4	8	0	3	7	0	0
9	18	5	3	8	3	3	4	0	5	5	4	3
10	7	7	0	0	7	0	4	3	4	0	5	1
11	4	18	3	0	3	8	0	0	0	0	11	0
12	3	13	5	5	5	5	4	0	5	5	3	1
13	11	18	7	13	0	0	0	3	5	0	4	5
14	18	13	0	13	8	7	3	3	3	2	7	1
15	4	3	5	18	8	4	0	5	4	0	5	3
16	7	11	3	16	8	0	3	8	7	3	11	5
17	3	11	13	18	8	0	3	5	0	4	7	8
18	4	8	18	11	5	0	0	4	0	3	8	0
19	7	0	18	22	13	0	8	3	3	4	7	11
20	7	3	8	5	7	0	7	5	7	6	7	5
21	7	8	18	13	0	3	3	7	4	0	4	7
22	0	8	18	8	15	1	0	0	7	0	5	3
23	0	5	8	4	1	5	0	6	0	0	3	5
24	4	5	3	0	4	5	4	8	7	2	0	0
25	4	8	8	0	2	7	5	7	4	2	3	7
26	4	0	7	0	......	8	3	3	8	7	4	7
27	0	8	0	8	......	5	0	8	4	0	3	5
28	7	8	5	5	0	8	0	0	7	0	7	11
29	3	......	8	3	2	4	3	7	15	11	4	5
30	3	......	8	8	0	9	0	0	0	8	7	7
31	8	......	5	......	5	......	0	3	......	......	......	5

THE ISTHMIAN CANAL PROBLEM.

The project of connecting the oceans by a waterway across the American Isthmus has attracted the attention of the world ever since the existence of the Isthmus became known. More than a dozen various routes have been advocated from time to time, the most northerly and one of the earlier being the Tehuantepec route, since famous as the ship-railway route of Captain Eads. An ordinary railway now crosses at this place.

The projects occupying most attention are the Nicaragua, Panama, Atrato, San Blas, and Caledonian.

ATRATO ROUTES.

The Gulf of Darien, an arm of the Caribbean Sea at the point where the Isthmus joins the main continent of South America, receives the waters of Atrato River, a navigable stream which flows due north

about 200 miles into the gulf. Its watershed is bounded on the west by the continental divide, which here hugs the Pacific coast very closely, and has several passes of moderate altitude.

Various projects have been proposed to utilize this river and its tributaries to approach the Pacific coast as nearly as possible, and then cut through the range to the sea. Of these projects the two that have received the most favor and attention are those which utilize the Napipi and Truando rivers, tributaries of the Atrato. Neither of these has been regarded with as much favor as the more northerly routes.

SAN BLAS ROUTE.

The San Blas route lies between the Gulf of San Blas in the Caribbean Sea and the mouth of the Bayano River on the Pacific. It is the narrowest part of the entire Isthmus, being only 30 miles from ocean to ocean. It is proposed that the level of the water in this canal be that of ordinary high tide in the Pacific Ocean. This route requires the construction of a tunnel several miles long, which it is proposed shall be 80 feet wide at the surface of the water and 140 feet high from the canal bottom.

CALEDONIA ROUTE.

A route across the Isthmus from Caledonia Bay was proposed and advocated by Dr. Cullen about 1850, but there was very little actual knowledge on which to base his opinions, and later examinations failed to confirm them.

The present Isthmian Canal Commission has caused a reconnaissance to be made of the entire Isthmus of Darien, which has resulted in the conviction that no other route compares in practicability with the Panama and Nicaragua routes.

PANAMA ROUTE.

The Panama route, though not in the narrowest part of the Isthmus, has a natural harbor on each coast, with a depression in the backbone of the cordillera only 363 feet above sea level. These natural advantages led to the construction in 1851 of the Panama Railway, from Colon on the Caribbean to Panama on the Pacific, to accommodate the heavy traffic consequent upon the discovery of gold in California. In 1878 De Lesseps inaugurated his celebrated attempt to cut a sea-level canal through this region without having made an adequate estimate of the cost, or even of the physical obstructions to be overcome. A large amount of work was actually done, the canal being practically completed for 7 miles on its northern end, and quantities of heavy excavation made in the upper and southern portions of the route. The sums actually subscribed and put into this work are variously stated as more or less than $260,000,000, not more than one-fourth of

which is represented by actual construction, the balance being squandered in corrupt and reckless extravagance; and the scandals occasioned thereby led to the bankruptcy of the company and the suspension of the work.

On the reorganization of the company a subscription of about $11,000,000 was obtained for surveys and construction. The new company very wisely sought the advice of a "Comité technique," composed of 14 eminent engineers, 7 of whom were French, and 7 elected from Germany, England, Russia, Colombia, and the United States, the latter being represented by Gen. Henry L. Abbot, United States Army, and Alphonse Fteley, chief engineer of the New York Aqueduct Commission. Under the direction of the "Comité technique" more complete surveys were made, the sea-level plan was abandoned, and plans were drawn up for a lock canal, which is to be supplied with water from reservoirs to be constructed on the Chagres River. A small force is, and has been for several years, at work on construction.

The Panama Canal follows the line originally adopted by the old company from Colon to Panama, is about 49 miles long from deep water to deep water, and is to have four locks on each side, with summit level at 98 feet. There is to be a large storage reservoir constructed at Alhajuela, on the Upper Chagres, 12 miles from the canal line, and a large aqueduct is to convey feed water from the reservoir to the summit level. Surplus waters are to be stored until safely discharged.

NICARAGUA ROUTE.

The same influence which prompted the construction of the Panama Railway led to the establishment of a transit route across Nicaragua, partly by water and partly by stage road, and surveys were made along this route for a ship canal by the transit company, and afterwards by the United States Government under Commander Lull. Later the Maritime Canal Company modified the plans, extended the surveys, and began construction on a ship canal. Financial difficulties, however, stopped the work before it was fairly under way, and agitation was carried on for some years to induce the United States Government to finance the project.

In 1895 Congress provided for a board of engineers to ascertain the feasibility, permanence, and cost of the canal, and appropriated the sum of $20,000 for the purpose. Col. William Ludlow, of the Army, Civil Engineer M. T. Endicott, of the Navy, and Mr. Alfred Noble, were appointed by President Cleveland to constitute it. Considering the time and funds at their disposal, this board made a very thorough examination of the route, the data, and the estimates, all of which were freely discussed and criticised. They reported that while the

canal was feasible the information collected was entirely inadequate as a basis upon which to make final estimates of cost, or even to determine approximate plans. They recommended, therefore, that an appropriation of $350,000 be made for further surveys and investigations. Accordingly a commission was appointed by President McKinley, consisting of Rear-Admiral J. G. Walker, Col. Peter C. Hains, and Lewis M. Haupt, for the further survey and examination of the canal route. This Commission inaugurated thorough surveys, which demonstrated the impracticability of certain features of the company's plans, and before its work was completed Congress provided in 1899 for increasing the Commission, and appropriated funds for the thorough examination, survey, and comparison of all the possible routes for an interoceanic canal across the Isthmus. The engineering portion of the Commission was reenforced by Col. O. H. Ernst, Alfred Noble, George S. Morison, and William H. Burr. Prof. Emory R. Johnson and Hon. Samuel Pasco were appointed as experts, respectively, on the commercial and political aspects of the problem. Explorations were made of the lower isthmus, east and south of Panama, which added largely to the topographic information there, but failed to reveal any favorable canal route, so that the problem was finally narrowed down to a comparison of the Panama and Nicaragua routes.

The route adopted by the Isthmian Canal Commission starts near San Juan del Norte on the Caribbean, runs in a general southwesterly direction across the swamps and lowlands north of Lake Silico, along the San Juanillo, and reaches the left bank of the San Juan River, near the head of the San Juanillo, about 20 miles from San Juan del Norte; it then follows on the left side of the river, but not in it, to Conchuda, about 3 miles above the mouth of the Rio San Carlos, passing through three locks on the way. A high dam near this point will raise the waters of the San Juan to the level of Lake Nicaragua, and the canal will enter the basin through two locks and follow the course of the river for the most part to Lake Nicaragua. Several cut-offs on the natural course of the river will be made, and above Castillo a large amount of dredging will have to be done to secure the required depth, and this will be continued far out into Lake Nicaragua. West of the lake the line runs by way of the valley of Las Lajas, cuts through the divide, and follows the Rio Grande Valley through four locks to the Pacific, where a harbor is to be constructed. The total length is about 187 miles, of which 49 miles is deep water in Lake Nicaragua, 17 miles in river not requiring improvement, leaving 121 miles of canalized river and canal proper. It is to have nine locks; the level of Lake Nicaragua and all the canal between Boca San Carlos and Bueno Retiro, the extremities of the summit level, are to be controlled between the limits of 104 and 111 feet above sea level, the surplus water being discharged into the Caribbean by way of the San Juan River.

The comparative length and direction of the Nicaragua and Panama canals is shown in Pl. XL.

COMPARISON OF CANAL ROUTES.

The value of an isthmian canal depends upon the difference between the tolls charged by the canal and the expense it saves in shortened voyages and transfers of freight. To be a public benefit its tolls must be less than the cost of transferring freight to the Panama Railroad, hauling it across the 47 miles of that line and reloading it on the other side.

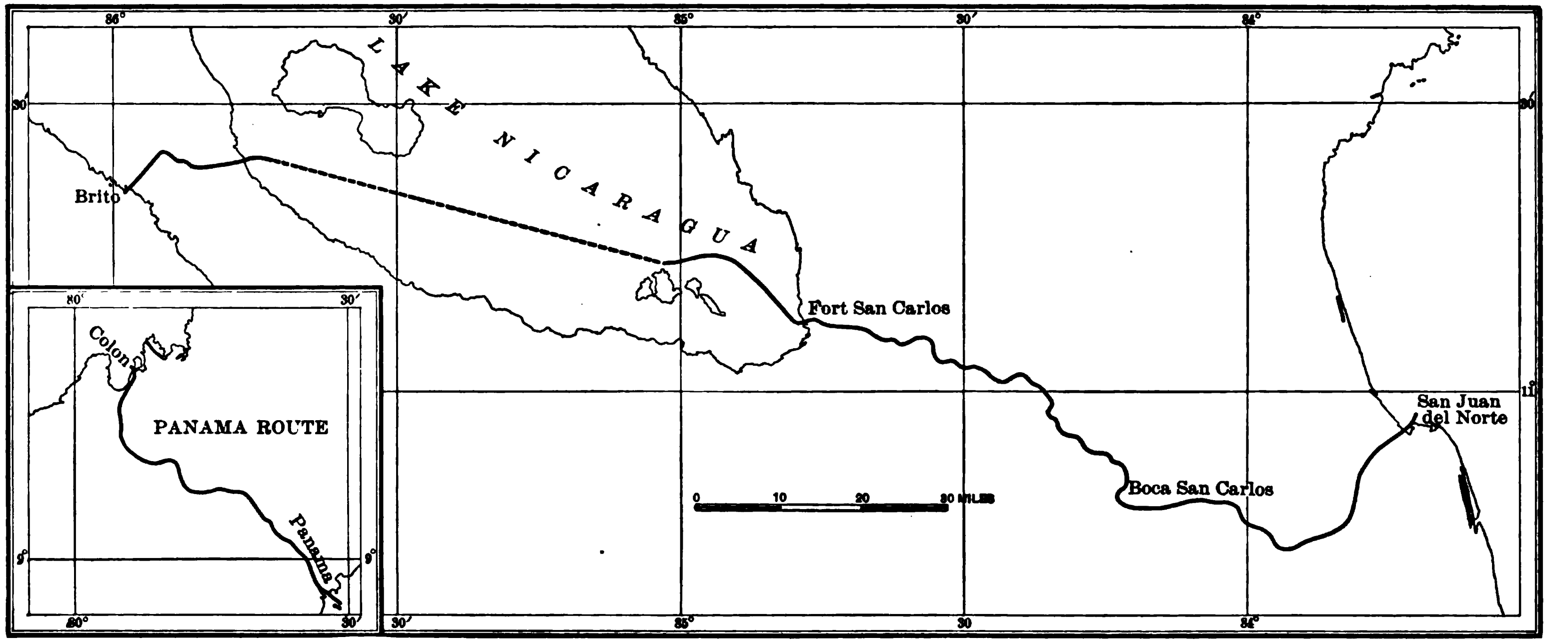
The canal will be compelled also to compete with the Tehuantepec Railway, 190 miles in length, on a route very much shorter between points in the northern hemisphere than by way of either canal. For these reasons to be successful the interoceanic canal must not only be a first-class canal, operated at low rates, but must be located on the most favorable route.

Investigations have shown that there are only two practicable routes, the Panama and Nicaragua. While both these routes involve engineering feats of great magnitude and difficulty, they are both entirely feasible. Both have ample and certain water supplies, and can control their surplus waters with certainty and safety. Both can be constructed in about ten years, and can be maintained in a high state of efficiency. In all these respects the routes are about equal.

No construction work has been done in Nicaragua, while in Panama about $60,000,000 worth of work has been done, but the partly constructed canal with its concession belongs to a French company which is prohibited from transferring it to any government. It might, however, relinquish its rights for a sufficient consideration, thus leaving the Colombian Government free to negotiate a new concession with the United States. The Isthmian Canal Commission in its preliminary report estimates that a canal of 35 feet depth, 150 feet bottom width, and duplicate locks of large dimensions, would cost $46,000,000 more at Nicaragua than the completion of the Panama Canal on a similar basis. We will assume that this figure represents the present value of the Panama Canal and that the works could be purchased and a satisfactory concession could be obtained from Colombia for that amount, making the completed canal cost the same as the Nicaragua.

It then remains to compare the canals as to cost of operation and maintenance and relative utility. In making this comparison we will adopt the plans recommended by the Isthmian Canal Commission and accept, as far as they go, the official estimates and figures.

It may be presumed that the tolls charged will be regulated according to the cost of maintenance and operation. To arrive at the cost of maintaining and operating the canal we have recourse to comparison



COMPARATIVE LENGTH OF PANAMA AND NICARAGUA CANALS.

Plans drawn to same scale.

with other canals already constructed and in operation. The following table shows the traffic and expenses for recent years of the principal canals of the world, according to their official reports:

Traffic and cost of operation of ship canals.

Year.	Traffic in tons.	Annual cost.	Cost per ton-mile.
Manchester, 35.5 miles:			
1898	2,595,585	$861,976	$0.0093
1899	2,778,108	927,140	0.0094
1900	3,060,516	1,004,333	0.0092
Mean cost per ton-mile			0.0093
Suez, 80 miles:			
1898	9,238,603	1,592,834	0.0022
1899	9,895,630	1,661,042	0.0021
1900	9,738,152	1,742,717	0.0022
Mean			0.0022
Kiel, 61.6 miles:			
1898	3,117,840	492,080	0.0026
1899	3,488,767	540,128	0.0025
Mean			0.0025
Sault Ste. Marie, 1.6 miles:			
1897	17,619,933	78,104	0.0028
1898	18,622,754	58,890	0.0020
1899	21,958,347	90,307	0.0026
1900	22,315,834	79,293	0.0022
Mean			0.0024

Average cost per ton-mile of all four, $0.0041.

These figures show a wide divergence in traffic cost, which may be explained in part by examination of the following table comparing the canals in length, alignment, locks, traffic, etc.:

Comparison of ship canals.

	Suez.	Manchester.	Kiel.	Panama.	Nicaragua.	Sault Ste. Marie.
Length, miles	88	35.5	61.6	49	184	1.6
In natural lakes	8	0	4	0	42	0
Bottom width, feet	122	120	72	150	150	108
Depth, feet	28	26	29.5	35	35	21
Cost—million dollars	115	76	37	184	189	7.85
Number of locks	0	5	2	5	9	1
Maximum lift, feet	0	16.5	16	43	37	18
Radius of sharpest curve, in feet	5,900	1,980	3,280	6,234	4,045	Infinite.
Percentage straight		56	63	57		100
Traffic began	1870.	1894.	1895.			1855.
Traffic, 1899, in thousand tons	9,985	2,778	3,489			21,958
Degrees of curvature				772	2,340	0

It will be noted that the Manchester has by far the shortest radius of curvature, and to this is largely due its excessive cost of operation. When a large vessel in a canal draws nearly as much water as the available depth she will not obey her rudder and it becomes impossible to steer her around short curves. For this reason when a very large vessel is taken through the Manchester Canal she is attended by two small tugs, one at the stern and one at the bow, to conduct her along the tortuous channel. The Suez Canal was constructed with curves of 2,300 feet radius, but these caused such annoyance that they were afterwards eliminated, and its shortest radius is now nearly three times that of Manchester. The Manchester also has 5 locks, or one to every 7 miles, and the smallest tonnage of all. These facts all tend to make up the high rate per ton-mile; but it is undoubtedly operated with economy, for it is at the very doors of the merchants who own it and are losing money on it every year. It may be assumed that they watch its expenditures with a jealous eye.

The Sault Ste. Marie, which shows very low figures, has one lock in its 1.6 miles, but it has no curvature, and its enormous traffic helps to keep down the rate. Still the low cost shows good management.

The Kiel Canal has nearly as low a rate as the Sault, with only one-sixth the traffic. Its two locks are only tidal locks with low average lift, and it must have been well constructed to keep its cost of maintenance down to a nominal sum.

The Suez Canal has gentler curves than the Kiel, a traffic nearly three times as large, and no locks at all. In all of these respects it has important advantages over the Kiel, and should, it would seem, show far smaller cost of operation, yet this is nearly as great. Several reasons for this suggest themselves. The Kiel, Manchester, and Sault canals are located near centers of manufacture and commerce, where materials and skilled labor can be obtained to the best advantage, while the Suez is relatively remote from such essentials, and drifting sands also increase the cost of its maintenance. The chief cause of the small cost of operation of the Kiel Canal may be that it is operated and maintained with wonderful economy, for which the credit is due to the thrifty German management, which, in its construction, furnished the world with one of the few examples of a gigantic and difficult engineering feat accomplished within the time and cost estimated, and did the work so well as to leave a low cost of maintenance. The Suez Canal may be taken as furnishing the minimum cost of operation and maintenance, and one which can not be equaled by the American canals, since it has no locks and they have many. They will also cost more than the Kiel, for it has one lock to 30 miles of canal, while Nicaragua has about one to 15 miles, and Panama one to 9 miles. This will increase the relative cost of the American canals, which will be augmented by their remoteness from

centers of commerce. They can not hope to have more than one-third or one-fourth the traffic of the Sault Ste. Marie, and consequently can not approach its rate. Being straighter and having relatively fewer locks than the Manchester the expenses can be kept below those of the latter.

The mean cost of the four canals given is 4.1 mills per ton mile, and is useful in estimating the cost of maintaining and operating an American canal.

The great cost of maintenance and operation of the Manchester, and the low cost of that of the Kiel, together with the complication of length, locks, and curvature on both, make it difficult to use their data in estimating the relative influence of each feature on the total annual cost. In the Sault, however, we have a canal without curvature, only 1.6 miles long, and with only one lock. Its cost is, therefore, chiefly the maintenance and operation of that lock, and is thus of value for comparison with the Isthmian canal locks. Though it handles a very much heavier traffic than the Isthmian canal will ever have, the latter will have to contend with a wet, tropical climate, and is remote from commercial centers, and these conditions will tend to increase its cost. We may, then, without important error, take $60,000 per annum as the cost of maintaining and operating each lock on the Isthmus.

The Suez Canal has no locks, has very gentle curvature, and carries a traffic similar in character and magnitude to that expected for an Isthmian canal. It is, therefore, of value in estimating the annual cost due to length only. It is greatly annoyed by drifting sands, which increase its cost. But, on the other hand, the Panama Canal receives the waters of the Upper Chagres into Lake Bohio, which, though not a muddy stream, may in the future require some attention, while the Nicaragua route receives the waters of a large number of small tributaries, and Greytown harbor will require constant dredging to counteract the tendency to close up under the littoral action on the sands. But these difficulties are not nearly so important as the drifting sands at Suez, and a much smaller figure should be taken for the American canals. From the above table we find the cost on Suez to average about $19,000 per mile. Adopting $15,000 for the mileage cost of the American canals, and $60,000 each for the locks, we have figures which should approximately satisfy the conditions on the Isthmian canals. They give results somewhat too small when applied to the Manchester, but large when applied to the Kiel.

The total length of the Nicaragua route is 184 miles, of which 42 are in the deep water of the lake, where vessels can travel at full speed, and are not properly part of the canal, leaving 142 miles of river and canal proper. Eighteen miles of the river require no improvement other than the construction of the dam, and will require little attention for

maintenance, but will require lighting, attendance of tugs, telegraph service, etc., and will be included in cost of operation and maintenance, while the lake will be excluded, though it will also require some lights, and telegraph wires must go around it.

The length of the Panama Canal is about 49 miles, of which 10 are in lake Bohio, which is really the Chagres River impounded by the Bohio dam; but being of the same nature as the 18 miles of San Juan River on the Nicaragua route it will, like that, be charged for operation and maintenance.

Taking these lengths, 142 miles for Nicaragua and 49 for Panama, on the above assumptions for cost of operation and maintenance, we obtain the following table:

Cost of operating Nicaragua and Panama canals.

For Nicaragua:	
Length, 142 miles, at $15,000 per mile	$2,130,000
Eight locks, at $60,000	480,000
Total annual cost	2,610,000
For Panama:	
Length, 49 miles, at $15,000 per mile	735,000
Five locks, at $60,000	300,000
Total annual cost	1,035,000

Assuming a traffic of 8,000,000 tons per annum, this would be nearly 33 cents per ton for Nicaragua and 13 cents for Panama, without including any allowance for Panama's advantage in curvature, which, as the table on page 541 shows, is considerable.

It now remains to compare, in view of the above, their respective advantages to commerce. A vessel can not, with a given power, move so rapidly through a canal as through deep water, and if she could it would not be safe to do so. It is essentially correct to assume that on an average vessels will move through the canal at half the speed they would accomplish at sea. To allow for this we will, in comparing distances through the canals, add 40 nautical miles to those via Panama and 120 to those via Nicaragua, and this will compensate for their difference in length, since this is about the length in nautical miles, in each case, which is equivalent to the delay by the canal proper. By comparison of distances computed on this basis we can determine their relative advantages to commerce.

No trade between Europe and the Orient can profitably use either the Panama or Nicaragua canal, the distance being very much shorter via Suez. Vessels from New York, bound for ports south of Hongkong, will go via Suez or Good Hope; but for Shanghai, Yokohama, or Manila, they can save time via the American canal, while Hongkong is so nearly equal as to bring into play the advantage offered by the Suez route of more frequent ports available for coaling and repairs,

and the Suez Canal would obtain the traffic unless a lower rate were offered by way of the American Isthmus.

It is estimated by good authorities that the average cost for carrying freight over long ocean voyages is one mill per ton-mile, of which one-half is for shore expenses, loading and unloading, warehouse, insurance, etc., leaving one-half mill per ton-mile for moving freight through the water.

There are eight typical routes of travel that would use an Isthmian canal. The following table shows the relative distances saved for these eight classes of traffic, allowing for delay in transit, due to canal length, as above indicated. The last column shows the amount per ton that vessels would save by going via Panama, on the assumption that both canals are open to traffic, and the tolls fixed to just cover cost of maintenance and operation, computed as above:

Comparison of distances saved by Nicaragua and Panama canals.

From—	To—	Via Nicaragua.	Via Panama.	Saving via Nicaragua.		Net advantage of Panama.
		Miles.	*Miles.*	*Miles.*	*Per ton.*	*Per ton.*
San Francisco	New York	5,040	5,340	300	$0.15	$0.05
Do	Liverpool	7,770	8,080	310	.16	.04
Do	New Orleans	4,240	4,740	500	.25	-.05
Yokohama	New York	10,870	11,050	180	.09	.11
Do	New Orleans	10,070	10,450	380	.19	.01
				Saving via Panama.		
Guayaquil, Ecuador	New York	3,370	2,910	460	0.23	.43
Do	Liverpool	6,100	5,650	450	.22	.42
Do	New Orleans	2,560	2,300	260	.13	.33

The fact is well established that Nicaragua is far more favorably located for the use of sailing vessels, being in the region of trade winds, while the Bay of Panama is subject to calms so prolonged as to seriously interfere with the arrival and departure of sailing ships, and it is not likely that such vessels would use the Panama Canal. About 8 per cent of the carrying trade of the world is done in sailing vessels, but, as pointed out in the preliminary report of the Commission, this is decreasing and likely to decrease in future, especially for Isthmian traffic. From one-third to one-fourth of such traffic would be with the west coast of South America, in which Panama's advantage in distance and tolls would offset her disadvantage in winds.

To sum up, sailing vessels to and from the North, or say 5 per cent of the total traffic, would prefer Nicaragua; steam vessels from Gulf ports to the west coast of North America, or perhaps 25 per cent of the total, would prefer Nicaragua, but might use either route with nearly equal advantage; while all the rest, or 70 per cent, would prefer Panama; and the traffic to and from the west coast of South America in steam vessels, or about 30 per cent, would, by way of Panama, save

an average of nearly 400 miles in distance and 20 cents per ton in tolls—always assuming that these are to be based on expenses.

There are many other questions to be considered in comparing these routes, the most important being those of health and facilities for local development. The Panama region is notorious for its liability to yellow fever and other tropical ailments, while, for a tropical region, Nicaragua is peculiarly healthy, and epidemics of yellow fever are unknown, though frequent both to the north and south. This adds importance to the further fact that in the vicinity of the Nicaragua Canal is a vast wilderness of immense agricultural and horticultural resources comparable in area and possible development with the State of Ohio, with a present population less than the city of Toledo.

The construction of the canal would furnish much-needed transportation facilities, to which Lake Nicaragua, San Carlos River and many smaller streams would become feeders, and the result would be an immense influx of American settlement and capital, the rapid development of agriculture, and the culture of bananas, coffee, rubber, and cacao. In a very short time American interests would unquestionably dominate.

There is no tropical region on the face of the earth so favorable for Caucasian immigration as the Nicaragua Canal region, on account of its cool trade winds and its remarkable healthfulness. With these conditions it combines an especially luxuriant vegetation, owing to the heaviest rainfall of any part of the Western Continent. There is thus a splendid opportunity to bring the highest type of civilization to a tropical gem of unsurpassed splendor. No such opportunity is presented at Panama.

HYDROGRAPHY OF NICARAGUA CANAL ROUTE.

The hydrographic investigations made for the Nicaragua Canal Commission were described in the Twentieth Annual Report of the Geological Survey, Part IV. The Isthmian Canal Commission being instructed to examine all possible routes, and "especially those known as the Panama and Nicaragua routes," the hydrographic inquiry was accordingly extended, and the writer was placed in charge of all such investigations on the Isthmus.

The hydrographic observations of the Isthmian Canal Commission consisted in the main of a continuation of those inaugurated by the Nicaragua Canal Commission, some extension of rainfall observations in the basin tributary to Lake Nicaragua being the principal difference.

The information required relates to the solution of four principal problems:

First. Water supply for the use of the canal and to replace loss by leakage and evaporation.

Second. The quantity of rainfall and volume of streams considered as obstacles to construction.

Third. The volume and habit of excessive floods with reference to their permanent control and discharge without injury to the canal or other property.

Fourth. The evaporation from Lake Nicaragua, this being the principal draft upon the water supply.

The desired information therefore required an investigation of the discharge of all streams of importance which it was proposed to control during construction, or for which it was necessary to provide diversion channels or spillways and measurements of rainfall at points as widely distributed as possible throughout the basin of Lake Nicaragua, San Juan River, and the adjacent region.

It also required an approximate determination of the rate of evaporation on Lake Nicaragua and some investigation of the sediment carried by the larger rivers.

The methods used in observing the discharge of streams were similar to those employed by the Geological Survey in the United States, cross sections being taken with sounding line and velocities usually measured by current meter.

PACIFIC SLOPE.

All streams with which the canal is concerned flow eventually into the Atlantic, except the Grande and its tributaries. This stream rises in the hills of the continental divide, and empties into the Pacific Ocean at Brito. The canal line follows its valley from the deep divide cut to the sea. The principal tributary is the Tola River, which enters from the north and which formerly, in common with the other headwaters of the Grande, flowed into Lake Nicaragua. The recession of the continental divide toward the lake turned them toward the Pacific, and the proposed canal cut through the divide is the site of the former stream bed of this drainage.

GRANDE AND TOLA RIVERS AT THEIR JUNCTION.

A gage was kept on the Grande River a short distance below the junction of the Tola, and the latter river was observed about a mile above its mouth.

During a portion of the dry season the Grande is entirely dry above the mouth of the Tola, and the waters of the latter are ponded for some distance up the Grande.

A perceptible quantity of the water is lost by evaporation and seepage from this pond, so that for a time the discharge of the Tola at the station was slightly greater than that of the Grande below the mouth of the Tola.

The largest flood yet observed at this station occurred on the 22d day of October, 1900, when 5,450 cubic feet per second was flowing in the Grande below the Tola.

Estimated monthly discharge of Grande River below mouth of Tola River.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1898.				
January 6 to 31	75	60	69	3,340
February	55	41	49	2,720
March	40	25	35	2,150
April	35	17	25	1,490
May	85	17	28	1,720
June	1,990	17	110	6,550
July	2,030	55	121	7,440
August	145	45	67	4,120
September	2,975	55	253	15,050
October	2,065	260	596	36,650
November	1,028	190	282	16,780
December	190	97	130	7,990
Total	2,975	17	148	106,000
1899.				
August 13 to 31	37	7	11	401
September	18	6	8	496
October	2,081	5	113	6,954
November	385	26	44	2,646
December	68	19	32	1,954
The year	2,081	5	44	12,451
1900.				
January	17	12	12	762
February	11	6	9	482
March	7	4	6	343
April	5	2	3	182
May	216	2	19	1,196
June	953	16	63	3,745
July	1,272	48	123	7,569
August	59	29	36	2,225
September	5,400	26	238	14,166
October	5,450	260	603	37,068
November	382	144	197	11,746
December	142	69	105	6,434
The year	5,450	2	119	85,918
1901.				
January	73	41	57	3,505
February	41	22	31	1,722
March	22	18	19	1,168

Estimated monthly discharge of Tola River one mile above its mouth.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1898.				
June 9 to 30	355.0	12.0	53	2,310
July	163.0	21.0	46	2,830
August	57.0	20.0	30	1,840
September	364.0	39.0	112	6,660
October	452.0	130.0	246	15,125
November	270.0	100.0	160	9,520
December	100.0	65.0	79	4,860
Total	452.0	12.0	106	43,145
1899.				
August 13 to 31	26.0	2.0	13	496
September	17.0	8.5	14	841
October	408.0	8.0	49	2,993
November	173.0	18.0	30	1,759
December	41.0	15.0	20	1,256
Total	408.0	2.0	26	7,345
1900.				
January	15.3	10.0	13	770
February	11.7	7.0	8	428
March	9.5	5.0	6	381
April	5.3	4.0	5	276
May	89.0	11.0	19	1,182
June	187.3	15.0	40	2,384
July	99.0	28.0	62	3,840
August	47.0	24.0	34	2,023
September	....	28.0	120	7,154
October	3,047.0	145.0	370	22,765
November	291.0	111.0	179	10,679
December	113.0	66.0	89	5,496
The year	3,047.0	4.0	77	57,378
1901.				
January	66.0	31.0	47	2,890
February	31.0	20.0	25	1,388
March	20.0	16.0	17	1,045

LAKE NICARAGUA.

Lake Nicaragua is one of the notable fresh-water lakes of the world. It has an area of 2,975 square miles. Its greatest length is from northwest to southeast, and is about 100 miles. Its extreme width is about 45 miles.

West of the center is an island occupied by the volcanoes Ometepe and Madera, which stand about 5,000 feet above the lake level, adding greatly to the scenic beauty.

The prevailing easterly trade winds cause a moderately heavy surf to beat almost constantly on the western shore, causing the formation of a decided beach on that side, while on the eastern shore aquatic vegetation grows far out into the water. This shore is flat and muddy, with no well-marked beach.

Except in the southeastern portion the lake is deep, reaching in one point near the southern foot of Madera a depth of 200 feet.

Lake Nicaragua receives the waters of a large number of tributaries, the most important being Frio and Pisote rivers, on the southern end, which rise in the high mountains of Costa Rica and maintain some flow throughout the dry season, and Malacatolla and Tipitapa on the northern end, the latter bringing the waters of Lake Managua. The drainage area, as estimated from the best information obtainable, is as follows:

Drainage area of Lake Nicaragua.

	Sq. miles.
Area of land surface draining directly to Lake Nicaragua	6,640
Area of Lake Nicaragua	2,975
Lake Managua and tributary basin	3,035
Total	12,450

STATION AT TIPITAPA.

The gage in this river is about 100 yards above Tipitapa Falls, and serves both to register the stage of the river and the height of Lake Managua, upon which the stage of the river depends. During low water the river was too sluggish above the falls for accurate measurement with current meter, and gagings were made from the bridge below the falls. As the river rose it became very turbulent and swift at the bridge, but at the same time the velocity in the upper river increased and good measurements were made above the falls. Observations of rainfall and evaporation were also made at this point.

Lake Managua lies to the northwest of Lake Nicaragua and drains into the latter through Tipitapa River. Its area is about 438 square miles.

Estimated monthly discharge of Tipitapa River at Tipitapa.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1898.				
February	125	37.0	77.0	4,275
March	36	3.0	16.6	1,020
April	4	0.0	0.5	29
May	18	0.0	3.8	234
June	700	13.0	121.0	7,200
July	922	280.0	662.0	40,700
August	930	487.0	626.0	38,490
September	3,230	910.0	2,045.0	121,690
October	5,580	2,910.0	4,040.0	248,410
November	5,500	2,150.0	3,640.0	216,600
December	2,630	1,470.0	1,950.0	119,900
1899.				
January 1 to 23	1,470	950.0	1,210.0	55,200
The year	5,580	0.0	1,208.0	853,748
August 20 to 31	5	3.0	4.0	97
September	7	2.0	4.5	266
October	631	2.0	101.5	6,244
November	824	517.0	612.7	36,459
December	824	308.0	545.0	33,505
Total	824	2.0	291.0	76,571
1900.				
January	316	148.0	223.0	13,724
February	137	58.0	94.0	5,232
March	55	5.7	25.0	1,515
April	13	0.4	8.0	474
May	17	0.2	5.0	309
June	358	12.0	173.0	10,277
July	1,275	284.0	919.0	56,500
August	1,348	749.0	974.0	59,900
September	866	762.0	801.0	47,667
October	2,804	832.0	1,527.0	93,917
Total	2,804	0.2	400.0	289,515

STATION AT FORT SAN CARLOS.

A gage was established at this point by Lieutenant Hanus, United States Navy, January 4, 1898. It was simply a graduated stick driven in the sand in shallow water and supported by two stakes in the form of braces. On March 13 a more substantial gage was placed in deeper water and firmly fastened to the iron remains of an old wreck of a Vanderbilt steamer about a quarter of a mile north of the town of San Carlos. It was driven as far as possible into the mud and fastened with bolts and cable to the iron wreck.

Bench mark No. 1 is on the highest point of the shore end of the stranded boiler and is 12.933 feet above the zero of the gage last described and 9.78 feet above the zero of gage established by Lieutenant Hanus. From the 8th of March, when a special observer was stationed at San Carlos, rainfall, evaporation, temperature, and humidity observations were taken.

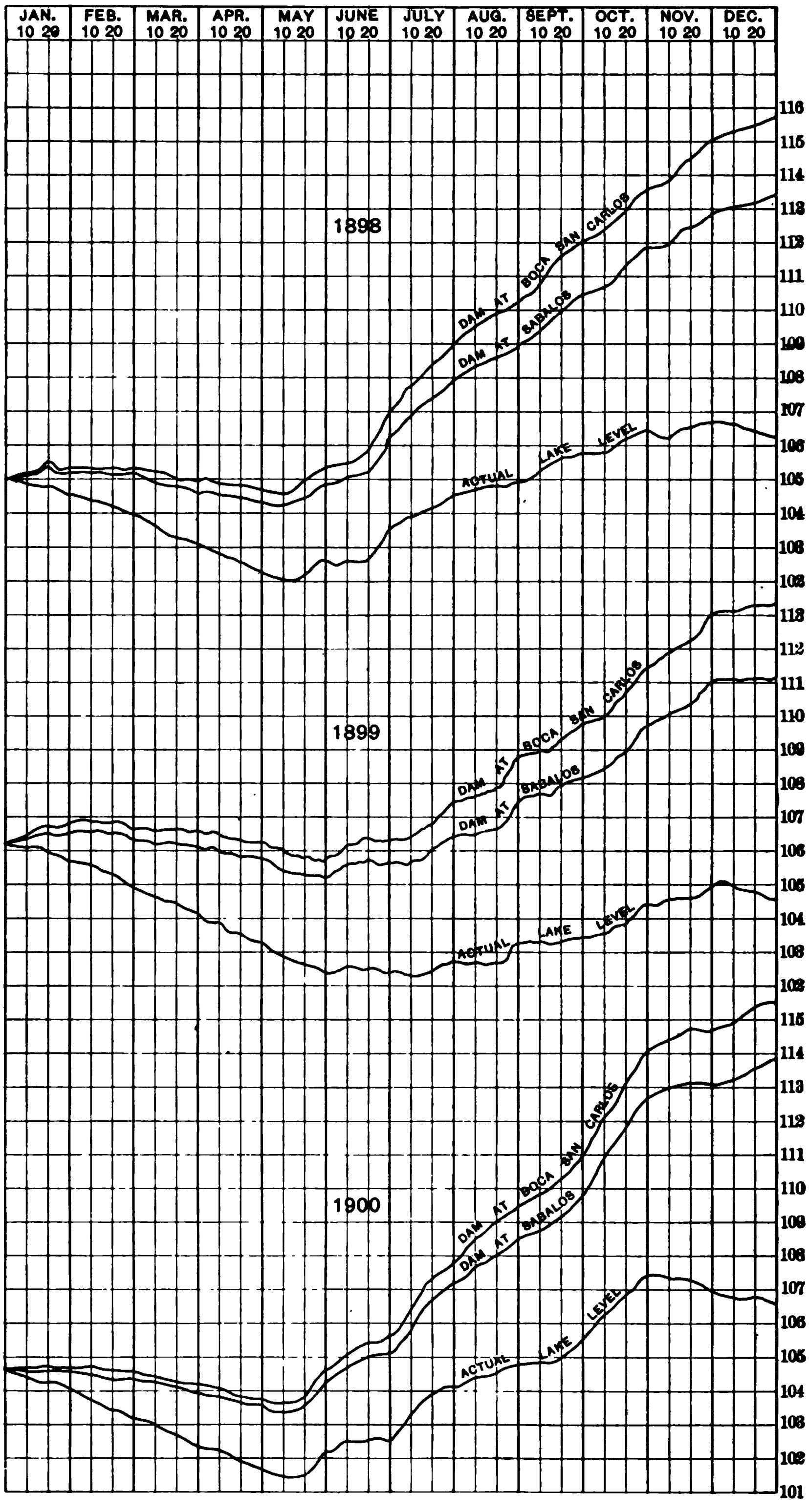
ELEVATION OF THE LAKE.

The rise and fall of the lake is the most important element in the measurement of the water supply for the summit level of the canal, the rate of inflow, and of evaporation. To obtain this element with the greatest possible accuracy, four gage rods were established at approximately equal intervals on the margin of the lake—at Sapoa, Granada, San Ubaldo, and Fort San Carlos—upon which daily observations were taken.

Daily elevation of Lake Nicaragua in 1898.

[Computed from gage-rod readings at Fort San Carlos, Jan. 4, 1898, to Dec. 31, 1898; Las Lajas, Feb. 8, 1898, to Dec. 31, 1898; Morrito, Apr. 9, 1898, to Sept. 21, 1898.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	104.49	103.86	103.02	102.29	102.48	103.50	104.56	104.96	105.66	106.41	106.64
2	....	104.42	103.89	103.02	102.24	102.49	103.47	104.51	104.97	105.74	106.37	106.63
3	....	104.52	103.82	102.98	102.23	102.44	103.55	104.51	104.95	105.76	106.31	106.59
4	104.92	104.48	103.86	102.96	102.21	102.39	103.70	104.58	104.94	105.74	106.26	106.65
5	104.96	104.51	103.78	102.92	102.20	102.42	103.62	104.61	104.97	105.75	106.22	106.67
6	105.02	104.43	103.75	102.96	102.20	102.45	103.78	104.57	105.05	105.73	106.26	106.62
7	104.93	104.43	103.76	102.92	102.14	102.52	103.79	104.60	105.02	105.75	106.22	106.64
8	104.94	104.43	103.73	102.86	102.12	102.49	103.82	104.70	105.05	105.79	106.19	106.56
9	104.88	104.42	103.72	102.83	102.11	102.48	103.90	104.67	105.05	105.73	106.22	106.55
10	104.79	104.32	103.62	102.77	102.09	102.48	103.89	104.65	105.11	105.73	106.21	106.58
11	104.85	104.30	103.64	102.81	102.08	102.48	103.96	104.65	105.19	105.71	106.26	106.57
12	104.87	104.31	103.62	102.81	102.04	102.54	103.99	104.59	105.29	105.75	106.34	106.55
13	104.80	104.41	103.61	102.76	101.96	102.51	103.98	104.74	105.44	105.75	106.46	106.49
14	104.76	104.32	103.52	102.74	102.03	102.47	103.98	104.73	105.45	105.84	106.42	106.49
15	104.75	104.29	103.57	102.69	101.97	102.48	104.03	104.78	105.48	105.88	106.47	106.47
16	104.79	104.23	....	102.68	102.05	102.44	104.07	104.80	105.53	105.86	106.50	106.50
17	104.78	104.21	....	102.68	102.01	102.47	104.04	104.83	105.58	105.92	106.50	106.44
18	104.83	104.21	....	102.65	102.13	102.47	104.07	104.78	105.57	106.08	106.57	106.44
19	104.84	104.16	103.26	102.61	102.10	102.59	104.10	104.78	105.57	106.14	106.51	106.39



OBSERVED FLUCTUATIONS OF LAKE NICARAGUA.

Daily elevation of Lake Nicaragua in 1898—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	104.97	104.14	103.30	102.55	102.11	102.65	104.25	104.78	105.58	106.15	106.44	106.41
21	104.90	104.08	103.33	102.59	102.15	102.70	104.17	104.82	105.65	106.13	106.62	106.37
22	104.82	104.04	103.14	102.56	102.43	102.91	104.25	104.83	105.71	106.24	106.56	106.32
23	104.73	104.00	103.27	102.53	102.40	102.97	104.23	104.77	105.66	106.28	....	106.37
24	104.64	104.08	103.29	102.45	102.51	103.01	101.32	104.80	105.74	106.36	....	106.39
25	104.71	104.04	103.30	102.43	102.57	103.09	104.33	104.81	105.72	106.35	....	106.35
26	104.70	104.06	102.99	102.44	102.55	103.04	104.35	104.78	105.68	106.36	106.54	106.33
27	104.69	103.94	103.19	102.42	102.59	103.16	104.39	104.83	105.63	106.38	106.59	106.29
28	104.67	103.93	103.12	102.37	102.56	103.30	104.46	104.82	105.74	106.34	106.62	106.27
29	104.52	....	103.09	102.33	102.46	103.42	104.38	104.94	105.76	106.44	106.63	106.38
30	104.64	....	103.10	102.32	102.55	103.47	104.54	104.95	105.75	106.41	106.70	106.37
31	104.57	....	102.97	....	102.50	....	104.51	104.96	....	106.38	....	106.44

Daily elevations of Lake Nicaragua in 1899.

[Obtained by averaging the daily elevation as indicated by gages at San Carlos, Granada, San Ubaldo, and Sapoa.[a]]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	106.23	105.73	105.01	104.10	103.25	102.41	102.35	102.69	103.35	103.46	104.37	105.02
2	106.08	105.70	104.88	104.03	103.29	102.45	102.35	102.69	103.33	103.41	104.35	105.05
3	106.19	105.69	104.85	104.02	103.31	102.43	102.38	102.70	103.33	103.46	104.33	105.09
4	105.97	105.68	104.90	103.93	103.19	102.35	102.44	102.66	103.31	103.44	104.33	105.01
5	106.10	105.64	104.85	103.95	103.24	102.38	102.41	102.68	103.32	103.44	104.38	105.03
6	106.15	105.68	104.79	104.01	103.02	102.48	102.37	102.69	103.32	103.46	104.37	104.99
7	106.00	105.68	104.92	103.99	103.09	102.45	102.35	102.70	103.31	103.48	104.36	104.92
8	106.05	105.66	104.73	103.94	103.06	102.53	102.36	102.63	103.32	103.47	104.41	104.91
9	106.09	105.56	104.65	103.78	102.97	102.46	102.27	102.64	103.32	103.47	104.58	104.96
10	106.06	105.58	104.66	103.86	102.89	102.48	102.31	102.64	103.29	103.48	104.57	104.96
11	106.08	105.55	104.58	103.82	102.89	102.68	102.28	102.71	103.29	103.52	104.59	104.94
12	106.04	105.61	104.54	103.69	102.88	102.47	102.21	102.67	103.26	103.55	104.58	104.90
13	106.02	105.39	104.55	103.62	102.76	102.64	102.24	102.65	103.24	103.57	104.58	104.89
14	106.00	105.25	104.57	103.70	102.74	102.52	102.36	102.63	103.25	103.73	104.54	104.91
15	106.01	105.30	104.58	103.62	102.72	102.53	102.38	102.62	103.21	103.89	104.54	104.90
16	105.92	105.40	104.49	103.59	102.72	102.56	102.38	102.63	103.15	103.88	104.49	104.91
17	105.98	105.40	104.45	103.63	102.73	102.46	102.33	102.59	103.14	103.86	104.53	104.89
18	106.09	105.30	104.53	103.63	102.72	102.56	102.36	102.63	103.17	103.80	104.54	104.86
19	105.99	105.26	104.47	103.60	102.70	102.50	102.44	102.67	103.18	103.81	104.58	104.78
20	106.04	105.32	104.50	103.57	102.61	102.75	102.41	102.68	103.36	103.84	104.58	104.82
21	105.92	105.20	104.44	103.48	102.64	102.57	102.54	102.67	103.31	103.86	104.57	104.75
22	105.93	105.17	104.34	103.46	102.61	102.50	102.53	102.69	103.33	103.95	104.60	104.72
23	105.89	105.14	104.38	103.47	102.60	102.42	102.59	102.73	103.37	104.01	104.64	104.73
24	105.78	105.18	104.32	103.40	102.56	102.49	102.56	102.80	103.38	104.07	104.65	104.71
25	105.76	105.11	104.29	103.37	102.52	102.49	102.58	102.86	103.39	104.10	104.70	104.63
26	105.74	105.19	104.23	103.33	102.56	102.46	102.60	103.07	103.45	104.14	104.67	104.65
27	105.74	105.03	104.15	103.34	102.53	102.45	102.67	103.22	103.42	104.24	104.72	104.62
28	105.75	104.89	104.20	103.32	102.57	102.36	102.69	103.22	103.41	104.37	104.79	104.59
29	105.72	....	104.19	103.32	102.42	102.43	102.68	103.27	103.41	104.36	104.80	104.57
30	105.71	....	104.17	103.24	102.43	102.44	102.71	103.31	103.42	104.38	104.98	104.52
31	105.75	....	104.19	....	102.35	....	102.73	103.29	....	104.39	....	104.53

[a] Jan. 1–23, San Carlos gage; Jan. 24–June 17, average of San Carlos and Granada gages; June 18–July 15, average of gages at San Carlos, Granada, and San Ubaldo; July 16–Dec. 31, averages of gages at San Carlos, Granada, San Ubaldo, and Sapoa.

Daily elevation of Lake Nicaragua in 1900.

[Obtained by averaging the daily elevation as indicated by gages at San Carlos, Granada, San Ubaldo. and Sapoa.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	104.55	103.96	103.28	102.42	101.75	102.14	102.66	104.12	104.73	105.49	107.42	106.94
2	104.50	103.95	103.23	102.37	101.72	102.16	102.71	104.10	104.71	105.70	107.42	106.90
3	104.46	103.91	103.23	102.33	101.69	102.17	102.79	104.11	104.75	105.78	107.38	106.87
4	104.43	103.92	103.17	102.28	101.63	102.17	102.80	104.11	104.79	105.89	107.36	106.89
5	104.44	103.92	103.09	102.27	101.59	102.17	102.73	104.22	104.83	105.91	107.36	106.89
6	104.44	103.87	103.14	102.30	101.66	102.22	102.87	104.31	104.82	105.98	107.33	106.81
7	104.40	103.85	103.12	102.27	101.56	102.21	102.95	104.33	104.79	106.20	107.32	106.83
8	104.38	103.87	103.13	102.29	101.52	102.32	102.93	104.32	104.81	106.18	107.34	106.79
9	104.42	103.80	103.09	102.25	101.56	102.40	103.03	104.36	104.85	106.18	107.32	106.74
10	104.37	103.78	103.06	102.21	101.53	102.48	103.21	104.38	104.84	106.20	107.30	106.78
11	104.39	103.74	103.03	102.17	101.50	102.48	103.33	104.43	104.83	106.31	107.35	106.79
12	104.37	103.74	103.00	102.16	101.42	102.48	103.43	104.45	104.85	106.37	107.35	106.78
13	104.40	103.70	103.01	102.09	101.47	102.45	103.42	104.46	104.84	106.43	107.33	106.80
14	104.30	103.69	102.99	102.11	101.48	102.48	103.58	104.51	104.81	106.44	107.34	106.78
15	104.32	103.61	102.97	102.10	101.43	102.45	103.69	104.48	104.81	106.47	107.32	106.76
16	104.30	103.59	102.92	102.09	101.37	102.47	103.66	104.47	104.89	106.50	107.30	106.76
17	104.27	103.53	102.89	101.94	101.38	102.50	103.78	104.52	104.91	106.63	107.29	106.71
18	104.28	103.52	102.82	101.98	101.33	102.54	103.78	104.51	104.94	106.66	107.30	106.68
19	104.25	103.43	102.77	101.97	101.35	102.56	103.89	104.48	104.94	106.69	107.27	106.76
20	104.21	103.45	102.77	101.94	101.51	102.55	103.89	104.57	105.03	106.75	107.22	106.77
21	104.20	103.45	102.69	101.94	101.41	102.60	103.97	104.56	105.06	106.95	107.22	106.73
22	104.18	103.42	102.67	101.91	101.49	102.63	103.95	104.62	105.05	107.07	107.17	106.73
23	104.17	103.43	102.67	101.90	101.46	102.63	104.02	104.65	105.09	107.24	107.16	106.71
24	104.16	103.51	102.62	101.87	101.48	102.67	103.99	104.66	105.14	107.32	107.12	106.69
25	104.18	103.41	102.62	101.85	101.58	102.61	104.03	104.62	105.17	107.37	107.12	106.69
26	104.15	103.29	102.66	101.86	101.72	102.63	104.05	104.71	105.19	107.37	107.11	106.67
27	104.12	103.35	102.61	101.85	101.87	102.60	104.04	104.70	105.18	107.42	107.05	106.61
28	104.10	103.28	102.73	101.80	101.87	102.65	104.05	104.70	105.20	107.41	107.05	106.63
29	104.00	....	102.51	101.75	101.99	102.64	104.04	104.72	105.32	107.41	107.03	106.64
30	103.90	....	102.52	101.75	102.09	102.53	104.09	104.73	105.43	107.39	106.99	106.63
31	103.99	....	102.45	....	102.12	....	104.09	104.75	....	107.39	....	106.59

Daily elevation of Lake Nicaragua in 1901.

[Obtained by averaging the daily elevation as indicated by the gages at San Carlos, San Ubaldo, Granada, and Tortuga.[a]]

Day.	Jan.	Feb.	Mar.	Apr.
1	106.52	105.50	104.81	104.04
2	106.51	105.53	104.80	104.11
3	106.50	105.46	104.90	104.05
4	106.41	105.49	104.78	104.11
5	106.41	105.48	104.74	103.98
6	106.38	105.39	104.70	103.90
7	106.36	105.35	104.69	103.84
8	106.33	105.35	104.79	103.85
9	106.31	105.33	104.76	103.89
10	106.35	105.29	104.72	103.75
11	106.34	105.26	104.69	103.82
12	106.30	105.25	104.66	103.66
13	106.26	105.22	104.63	103.72
14	106.30	105.21	104.61	103.63

[a] San Ubaldo discontinued on February 24; Tortuga discontinued February 28.

Daily elevation of Lake Nicaragua in 1901—Continued.

Day.	Jan.	Feb.	Mar.	Apr.
15	106.28	105.15	104.59	103.43
16	106.20	105.13	104.49	103.48
17	106.16	105.12	104.44	103.46
18	106.09	105.18	104.40	103.38
19	105.96	105.18	104.44	103.33
20	105.93	105.15	104.48	103.23
21	105.89	105.03	104.42	103.28
22	105.94	105.03	104.45	103.33
23	105.87	104.98	104.34	103.30
24	105.83	104.95	104.46	103.28
25	105.80	104.95	104.31	103.35
26	105.78	104.92	104.34	103.16
27	105.74	104.82	104.40	103.16
28	105.70	104.86	104.29	103.28
29	105.65	....	104.21	103.04
30	105.63	....	104.20	103.04
31	105.62	....	104.18	....

Estimated monthly flow into Lake Nicaragua in excess of evaporation.

Month.	Acre-feet stored in lake.	Acre-feet outflow.	Total in acre-feet.	Net inflow in second-feet.
1898.				
January 4 to 31, inclusive.	− 666,400	+ 1,032,400	+ 366,000	+ 6,590
February	−1,218,600	+ 923,800	− 294,800	− 5,310
March	−1,827,800	+ 863,600	− 964,200	−15,680
April	−1,237,600	+ 724,100	− 513,500	− 8,630
May	+ 342,700	+ 723,300	+ 1,066,000	+17,340
June	+1,846,900	+ 841,600	+ 2,688,500	+45,200
July	+1,980,200	+ 1,190,900	+ 3,171,100	+51,570
August	+ 856,800	+ 1,202,200	+ 2,059,000	+33,490
September	+1,504,200	+ 1,313,600	+ 2,817,800	+47,350
October	+1,199,500	+ 1,440,600	+ 2,640,100	+42,960
November	+ 609,300	+ 1,512,000	+ 2,121,300	+35,650
December	− 495,000	+ 1,540,000	+ 1,045,000	+16,990
The year	....	....	+16,202,300	....
1899.				
January	−1,313,760	+ 1,443,254	+ 129,494	2,106
February	−1,637,440	+ 1,154,774	− 482,666	− 8,691
March	−1,332,800	+ 1,103,500	− 229,300	− 3,729
April	−1,808,800	+ 896,008	− 912,792	−15,341
May	−1,694,560	+ 788,584	− 905,976	−14,735
June	+ 171,360	+ 765,329	+ 936,689	15,743
July	+ 552,160	+ 881,716	+ 1,433,876	23,319

Estimated monthly flow into Lake Nicaragua in excess of evaporation—Continued.

Month.	Acre-feet stored in lake.	Acre-feet outflow.	Total in acre-feet.	Net inflow in second-feet.
1899.				
August	+1,066,240	+ 944,463	+ 2,010,703	32,537
September	+ 247,520	+ 1,021,693	+ 1,269,213	21,331
October	+1,846,880	+ 1,115,681	+ 2,962,561	48,179
November	+1,123,360	+ 1,211,088	+ 2,334,448	39,234
December	− 856,800	+ 1,250,254	+ 393,454	6,399
The year	−3,636,640	+12,576,344	+ 8,939,704	....
1900.				
January	−1,028,160	+ 1,083,292	+ 55,132	897
February	−1,351,840	+ 836,958	− 514,882	− 9,270
March	−1,580,320	+ 755,503	− 824,817	−13,413
April	−1,332,800	+ 662,265	− 670,535	− 1,295
May	+ 704,480	+ 671,212	+ 1,375,692	22,372
June	+ 780,640	+ 741,117	+ 1,521,757	25,575
July	+2,970,240	+ 1,073,149	+ 4,043,389	65,756
August	+1,256,640	+ 1,288,735	+ 2,545,375	41,395
September	+1,294,720	+ 1,266,473	+ 2,561,193	43,045
October	+3,731,840	+ 1,752,367	+ 5,484,207	89,189
November	− 761,600	+ 1,679,231	+ 917,631	15,422
December	− 761,600	+ 1,653,969	+ 892,369	14,512
The year	+3,922,240	+13,464,271	+17,386,511	....
1901.				
January	−1,846,880	+ 1,446,800	− 400,080	− 6,510
February	−1,447,040	+ 1,117,300	− 329,740	− 5,940
March	−1,294,720	+ 1,068,470	− 226,250	− 3,680
April	−2,170,560	+ 838,470	− 1,332,090	−22,390

SAN JUAN RIVER.

The San Juan River is the sole outlet of Lake Nicaragua and its tributary drainage basin. Its total length from the lake to the sea is 122 miles, and it is usually navigable for light-draft river steamers. It leaves the lake at Fort San Carlos at an altitude varying from about 97 feet to about 110. Its course for a distance of 27 miles is through a low, swampy country, relieved by occasional hills. Through this portion the river is sluggish and receives several tributaries of small discharge, which in the dry season are practically still water. The principal of these are the Melchora, Medio Queso, Palo de Arco, and Negro. The first tributary of importance to the San Juan River is

the Sabalos, which enters from the north and empties 27 miles east of Fort San Carlos. About half a mile below the mouth of the Sabalos are the first rapids, called Toro Rapids. These rapids are caused by bowlders and gravel, probably brought into the river by the Sabalos in former times, but do not seriously obstruct navigation except in times of extremely low water. Below this point the San Juan receives the waters of a few streams, the principal of which are the Poco Sol and the Santa Cruz. Ten miles below Toro Rapids occur the largest rapids on the river, at Castillo Viejo. At this point the river falls about 5 feet in a few hundred feet, and steamers are seldom taken over the rapids except in high water. A railroad about 2,000 feet long is provided for the portage of freight and passengers on the right bank of the river.

Below Castillo are the Diamond, Balas, and Machuca rapids, the latter being 12 miles from Castillo. All of these rapids admit the passage of river steamers except at extreme low water. Below Machuca there are no more rapids. The river is deep and sluggish for a distance of about 15 miles to the point where it receives the waters and sediment of the San Carlos. This river is the largest tributary of the San Juan, rising far to the southward in the mountains of Costa Rica, and bearing such a volume of sediment that a delta has been built up at its mouth, and from this point to the sea the San Juan is a shallow stream with sandy, shifting bed. Twenty-five miles farther down the Sarapiqui empties into the San Juan from Costa Rica, being the second tributary in size to the San Carlos, and, like the latter, bearing large quantities of sediment in times of flood. Eight miles below the mouth of the Sarapiqui the San Juan assumes decidedly the character of a deltaic stream and sends out a small tributary known as the San Juanillo, which meanders through the swamps to the northward and, after receiving the drainage of the Deseado, reenters the San Juan 4 miles above its mouth. Five miles below the exit of the San Juanillo, or 103 miles from Lake Nicaragua, the main stream of the San Juan separates into two large distributaries, the larger, called the Colorado, flowing eastward directly to the Caribbean, and the smaller, or Lower San Juan, meandering to the northeast and finding its exit into the ocean at San Juan del Norte. Between the mouth of the Colorado and the Lower San Juan another distributary, called the Taura, finds its way from the Lower San Juan to the sea.

The principal obstructions to free navigation of light-draft river craft from San Juan del Norte to Fort San Carlos are due to the shoal character of the Lower San Juan, especially in times of low water, and to the rapids lying between Machuca and the mouth of the Sabalos. For purposes of a ship canal the river also requires deepening below the mouth of the San Carlos and between the Sabalos and Fort San Carlos.

The only portion of the river which is suitable in its present state for a ship canal is the part from Machuca to a point a short distance above Boca San Carlos, or about 15 miles out of 122, and even here some dredging must be done and two sharp bends eliminated to permit the safe passage of the largest ships.

Rating table for San Juan River at Fort San Carlos.

Lake height.	Discharge.	Lake height.	Discharge.	Lake height.	Discharge.	Lake height.	Discharge.
Feet.	*Sec. feet.*	*Feet.*	*Sec. feet.*	*Feet.*	*Sec. feet.*	*Feet.*	*Sec. feet.*
96.0	3,000	99.0	6,770	102.0	11,500	105.0	19,325
96.2	3,230	99.2	7,050	102.2	11,850	105.2	19,980
96.4	3,460	99.4	7,330	102.4	12,215	105.4	20,680
96.6	3,690	99.6	7,620	102.6	12,590	105.6	21,435
96.8	3,930	99.8	7,920	102.8	13,000	105.8	22,195
97.0	4,170	100.0	8,220	103.0	13,450	106.0	22,995
97.2	4,410	100.2	8,530	103.2	13,910	106.2	23,795
97.4	4,660	100.4	8,840	103.4	14,410	106.4	24,790
97.6	4,910	100.6	9,155	103.6	14,950	106.6	26,290
97.8	5,160	100.8	9,475	103.8	15,490	106.8	27,920
98.0	5,420	101.0	9,795	104.0	16,080	107.0	28,560
98.2	5,680	101.2	10,115	104.2	16,725	107.2	29,200
98.4	5,945	101.4	10,450	104.4	17,375	107.4	29,900
98.6	6,215	101.6	10,800	104.6	18,025	107.5	30,250
98.8	6,490	101.8	11,150	104.8	18,675		

SAN JUAN RIVER ABOVE LOS SABALOS.

A record has been kept of the discharge of the river at this point ever since January, 1898. The station used during 1898 and a portion of 1899 was found objectionable in some respects, especially showing evidence at times of being affected by high water in the Sabalos River, which enters the San Juan half a mile below. In October, 1899, a gage was placed farther up the river, at the mouth of an insignificant tributary called Farina. The discharge at this point is the same as that previously occupied, there being no tributaries between. This gage was connected with the bench mark of the precise levels, showing the zero of the rod to be at elevation 90.794 feet above sea level.

In October, 1899, a gage rod was placed on the right bank of the San Juan one-half mile below the east end of Isla Grande, near station 121 of the river survey. The zero of this is 95.29 feet above sea level. Occasional readings were taken of this gage when convenient to compare with those observed at Los Sabalos for determining the slope of the river between the gages. Eight cross sections were measured between these points at known gage heights by Mr. H. C. Hurd, showing the average cross section of 8,714 square feet with the Isla Grande gage rod at 4.9. Cross section No. 3, which occurs just above Isla Chica, a mile below the upper slope rod, gives an area of 8,799 square feet.

SAN JUAN RIVER, LOOKING UPSTREAM FROM LOS SABALOS.

Estimated monthly discharge of San Juan River at Station Sabalos.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1899.				
January	25,100	21,810	23,472	1,443,254
February	21,720	19,480	20,792	1,154,774
March	19,480	16,560	17,946	1,103,500
April	16,618	13,780	15,658	896,008
May	14,421	12,176	12,825	788,584
June	13,730	11,942	12,862	765,329
July	17,519	12,418	14,193	881,716
August	19,904	13,680	15,360	944,463
September	25,310	15,134	17,170	1,021,693
October	20,593	15,469	18,144	1,115,681
November	21,865	16,135	20,353	1,211,088
December	21,653	17,213	20,333	1,250,254
The year	25,310	11,942	17,370	12,576,344
1900.				
January	18,943	16,600	17,618	1,083,292
February	16,320	13,800	15,070	836,958
March	13,635	11,520	12,287	755,503
April	11,540	10,407	11,128	662,265
May	12,588	10,263	10,916	671,212
June	15,536	11,420	12,455	741,117
July	22,816	12,368	17,453	1,073,149
August	27,968	17,649	20,959	1,288,735
September	25,784	19,338	21,283	1,266,473
October	34,800	23,466	28,499	1,752,367
November	29,200	25,345	28,220	1,679,231
December	28,640	25,168	26,915	1,653,969
The year	34,800	10,263	18,600	13,464,271
1901.				
January	25,110	21,810	23,530	1,446,800
February	21,470	18,560	20,118	1,117,300
March	19,110	15,980	17,377	1,068,470
April	15,880	12,530	14,091	838,470

OCHOA STATION ON SAN JUAN RIVER.

A camp was continued at this point under charge of Mr. H. S. Reed, keeping rainfall and temperature records and rod readings on the river. Measurements of discharge were made from a boat, its position at each observation being determined by stadia from shore.

From this station records were kept for the Machado River.

Records were also kept of gage height, discharge, rainfall, and sediment at the station on San Carlos River.

From the time when the camp on the San Carlos was removed August 31, 1898, to May, 1901, daily trips were made to the San Carlos station, never omitting a day. Therefore, we have over three years'

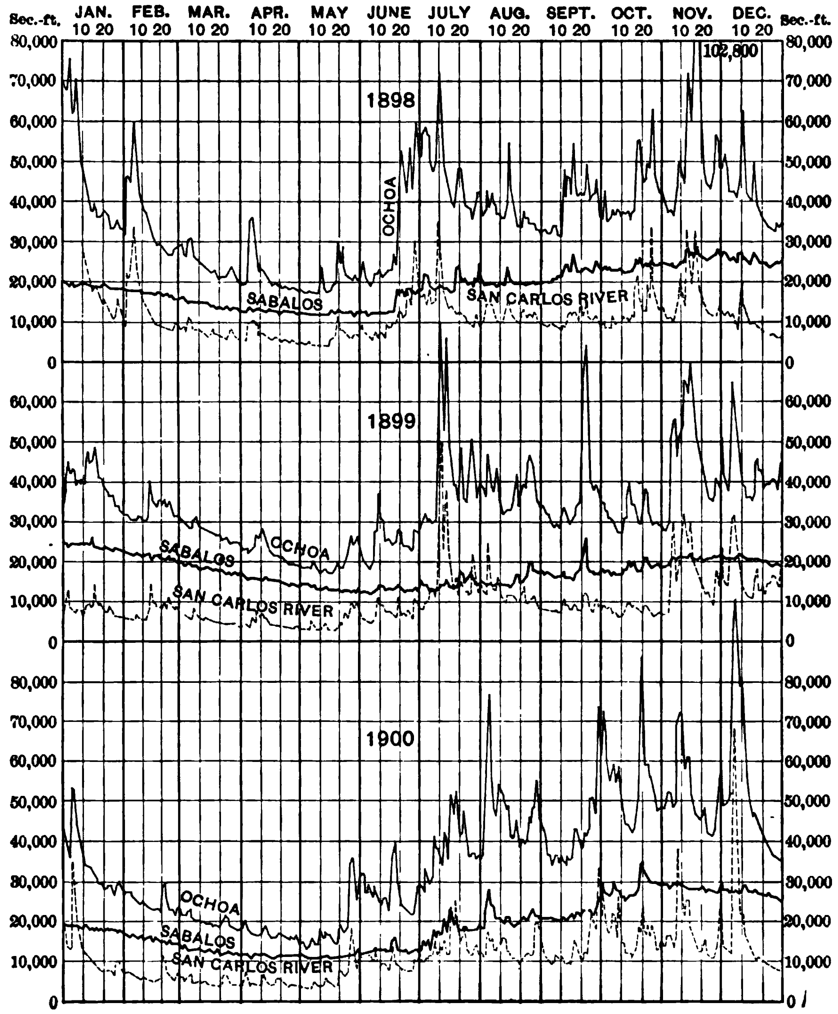


FIG. 228.—Comparative discharge of San Juan and San Carlos rivers.

complete record of discharge for both the San Carlos near its mouth and the San Juan at Ochoa. By taking the difference between them we obtain the discharge of the San Juan above Boca San Carlos, and by deducting from this the discharge measured at Sabalos we obtain the discharge of the tributaries between Sabalos and Boca San Carlos. The comparative flow of the San Carlos and the San Juan at Ochoa and at Sabalos is shown in fig. 228.

List of discharge measurements made on San Juan River at Ochoa.

[By H. S. Reed with Price meter No. 65.]

Date.	Gage height.	Area of section.	Mean velocity.	Discharge.	Wetted perimeter.	Hydraulic radius.	Slope.	"n."
1899.	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Feet.*			
October 5	7.90	9,204	3.55	32,693	866	10.63	0.000187	0.029
October 6	7.31	8,713	3.41	29,731	865	10.07	0.000190	0.029
October 10	6.84	8,079	3.40	27,453	864	9.35	0.000197	0.028
October 28	7.21	8,554	3.46	29,633	865	9.89	0.000206	0.029
November 5	11.21	12,617	4.16	52,476	878	14.37	0.000190	0.030
November 6	13.38	15,301	4.63	70,870	886	17.27	0.000192	0.031
November 8	10.49	12,147	3.94	47,868	875	13.88	0.000185	0.031
November 15	14.31	16,678	4.50	74,882	896	18.63	0.000160	0.031
November 25	8.51	10,373	3.52	36,500	868	11.96	0.000180	0.031
December 1	10.97	12,964	3.86	50,057	875	14.82	0.000183	0.033
December 6	12.14	13,864	4.33	60,105	877	15.81	0.000180	0.030
December 12	9.24	11,006	3.64	40,020	863	12.74	0.000178	0.031
December 16	8.31	10,099	3.54	35,735	867	11.65	0.000176	0.030
1900.								
January 4	8.63	10,289	3.73	38,346	860	11.97	0.000180	0.029
January 6	11.28	12,742	4.10	52,194	876	14.55	0.000173	0.030
January 24	7.01	8,621	3.29	28,396	863	9.99	0.000173	0.029
January 27	7.17	8,721	3.42	29,824	863	10.11	0.000180	0.028
January 30	6.89	8,366	3.37	28,164	862	9.71	0.000176	0.028
February 15	5.81	7,219	3.15	22,746	862	8.37	0.000183	0.027
February 26	5.57	7,223	3.03	21,913	861	8.39	0.000180	0.028
March 9	5.16	6,926	2.98	20,647	857	8.08	0.000182	0.028
March 16	4.97	6,467	2.90	18,711	857	7.55	0.000176	0.027
March 30	4.63	6,317	2.86	18,085	855	7.39	0.000166	0.026
April 5	4.55	6,116	2.84	17,358	855	7.16	0.000173	0.026
April 12	4.36	5,930	2.77	16,551	853	6.95	0.000173	0.027
April 25	3.97	5,980	2.79	16,694	850	7.03	0.000173	0.027
April 28	4.02	5,622	2.77	15,560	851	6.61	0.000169	0.025
May 1	3.85	5,453	2.77	15,079	850	6.42	0.000169	0.025
May 5	3.48	5,048	2.69	13,560	847	5.96	0.000176	0.025
May 21	4.74	6,280	3.04	19,101	859	7.31	0.000178	0.025
May 28	8.60	10,000	3.59	35,880	860	11.64	0.000173	0.029
June 2	6.48	8,305	3.21	26,685	865	9.60	0.000187	0.030
June 11	6.07	7,872	3.16	24,843	863	9.12	0.000187	0.029
June 18	8.96	10,508	3.66	38,405	862	12.18	0.000176	0.030
June 21	6.40	7,994	3.16	25,272	864	9.24	0.000183	0.029
June 28	5.59	7,316	3.10	22,702	863	8.48	0.000187	0.028
July 2	6.79	8,629	3.41	29,407	867	9.96	0.000187	0.029
July 12	8.20	9,497	3.66	34,758	867	10.95	0.000182	0.028
July 14	9.47	10,473	3.90	40,800	865	12.11	0.000173	0.027
July 16	10.92	11,804	4.28	50,513	874	13.51	0.000189	0.028
August 4	12.47	13,923	4.38	61,026	879	15.84	0.000190	0.031
August 7	11.64	13,223	4.09	54,128	877	15.08	0.000173	0.030
August 12	10.97	12,142	4.11	49,880	875	13.87	0.000190	0.030
August 30	11.36	12,698	4.22	53,523	876	14.50	0.000180	0.029
September 4	8.60	10,169	3.55	36,064	860	11.82	0.000183	0.031
September 18	10.08	11,582	3.78	43,791	869	13.33	0.000178	0.031
September 21	9.00	10,475	3.60	37,709	862	12.15	0.000185	0.031
September 29	12.05	13,287	4.29	57,035	878	15.13	0.000180	0.030
September 30	14.83	16,501	4.69	77,429	897	18.40	0.000169	0.030
October 3	14.08	15,395	4.72	72,721	893	17.24	0.000167	0.028
October 10	13.05	14,333	4.35	62,427	884	16.21	0.000183	0.031

NOTE.—Slope rod established October 4, 1899.

Estimated monthly discharge of San Juan River at Ochoa.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1898.				
January	75,200	32,240	45,250	2,782,300
February	58,530	26,080	35,400	1,966,000
March	30,650	20,140	23,800	1,463,400
April	40,380	17,290	21,150	1,258,510
May	34,880	16,300	19,640	1,207,600
June	60,180	18,890	33,140	1,971,970
July	78,050	35,540	46,810	2,878,200
August	54,100	32,020	37,230	2,289,200
September	54,100	30,920	39,530	2,352,200
October	67,625	34,600	42,200	2,594,800
November	107,000	37,080	51,890	3,087,670
December	65,000	32,790	40,850	2,511,770
The year	107,000	16,300	36,408	26,363,620
1899.				
January	49,100	32,000	39,665	2,438,900
February	41,120	29,840	32,540	1,807,180
March	31,300	23,900	26,940	1,656,480
April	28,834	18,500	21,987	1,308,222
May	27,294	16,780	19,533	1,201,079
June	36,399	17,900	24,624	1,465,351
July	80,626	28,050	42,783	2,630,645
August	58,624	31,900	37,931	2,332,348
September	77,321	29,050	35,963	2,139,978
October	39,000	27,350	31,769	1,953,350
November	74,882	27,800	46,133	2,746,154
December	64,190	34,950	42,763	2,629,458
The year	80,626	16,780	33,553	24,309,145
1900.				
January	53,280	27,150	33,968	2,089,746
February	29,300	21,750	24,235	1,345,993
March	22,065	17,220	19,664	1,209,122
April	19,725	14,680	16,469	979,978
May	36,050	13,245	18,413	1,132,212
June	39,400	20,850	26,386	1,570,119
July	53,100	29,200	38,494	2,366,930
August	76,470	36,050	47,131	2,898,042
September	77,429	33,950	41,039	2,442,026

GAGING SAN JUAN RIVER AT OCHOA.

A. MOUTH OF DANTA ON SAN JUAN RIVER.

Boat entering the Dante.

B. SAN JUAN RIVER NEAR PUNTA PETACA.

Estimated monthly discharge of San Juan River at Ochoa—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1900.				
October	87,696	42,965	55,259	3,298,815
November	72,680	41,300	51,838	3,084,600
December	106,600	35,300	52,889	3,252,040
The year	106,600	13,245	35,484	25,669,630
1901.				
January	61,900	30,350	35,310	2,171,130
February	31,810	23,710	26,910	1,494,500
March	24,900	19,800	22,180	1,363,800
April	19,680	16,600	17,900	1,065,120

Estimated monthly discharge of San Carlos River 3 miles above its mouth.

[Drainage area, 1,450 square miles, approximately.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1898.							
January 10-31	28,000	10,560	16,055	700,582	11.10	9.09	....
February	34,300	7,400	13,530	751,380	9.30	9.68	....
March	11,341	5,140	7,030	432,260	4.80	5.53	7.52
April	10,080	4,220	6,038	359,285	4.20	4.69	11.66
May	11,880	4,100	5,560	341,870	3.80	4.38	20.12
June	32,250	5,200	10,720	637,880	7.40	8.26	20.79
July	41,600	8,400	14,094	866,605	9.70	11.18	18.26
August	15,730	8,800	10,990	675,750	7.6	8.76	11.68
September	14,200	7,420	10,319	614,023	7.1	7.92	....
October	32,500	8,180	12,880	791,960	8.9	10.26	....
November	32,260	9,680	15,440	918,750	10.6	11.88	....
December	19,920	5,850	9,290	571,220	6.4	7.38	....
The year	41,600	4,100	10,996	7,661,565	....	....	....
1899.							
January	14,200	5,720	7,865	483,600	5.42	6.25	....
February	17,340	4,940	7,360	408,750	5.08	5.29	....
March	8,060	4,300	5,400	332,030	3.72	4.29	....
April	7,280	3,120	4,410	262,457	3.04	3.39	....

Estimated monthly discharge of San Carlos River 3 miles above its mouth—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1899.							
May	10,100	2,800	4,559	280,308	3.14	3.62	....
June	12,314	4,360	7,381	439,206	5.09	5.68	....
July	50,130	8,700	16,909	1,039,701	11.66	13.44	....
August	24,360	8,290	11,678	718,067	8.05	9.28	....
September	12,100	6,560	8,467	500,829	5.84	6.52	....
October	9,757	6,440	7,808	480,701	5.38	6.20	[a] 6.03
November	34,737	6,320	17,106	1,027,893	11.79	13.15	20.32
December	31,480	10,380	16,057	991,347	11.07	12.76	16.03
The year	50,130	2,800	9,583	6,967,889	....	....	....
1900.							
January	35,457	6,776	11,670	717,543	8.05	9.28	8.79
February	10,783	4,580	5,946	330,249	4.10	4.27	4.96
March	5,840	3,520	4,525	278,257	3.05	3.52	6.56
April	6,752	3,320	4,316	256,835	2.98	3.32	3.00
May	18,000	2,848	5,844	369,353	4.03	4.65	15.42
June	14,496	6,560	9,530	567,079	6.57	7.33	11.26
July	26,074	9,596	13,665	840,358	9.42	10.86	15.53
August	20,120	9,512	13,187	817,815	9.10	10.49	22.72
September	34,608	8,924	12,936	769,784	8.92	9.95	21.36
October	27,840	11,276	17,202	1,057,745	11.86	13.67	6.45
November	38,432	10,524	17,380	1,034,237	11.98	13.36	16.56
December	66,820	7,320	16,256	999,545	11.21	13.02	24.69
The year	66,820	2,848	11,038	8,038,800	....	....	....
1901.							
January	38,300	5,610	10,057	618,380	6.94	8.00	....
February	9,230	4,300	6,116	338,660	4.22	4.39	....
March	5,920	3,580	4,376	269,070	3.02	3.48	....
April	4,450	2,830	3,417	203,330	2.36	2.63	....

[a] From October 12 to 31, inclusive.

Estimated monthly discharge of San Juan River above the mouth of the San Carlos.

[This is obtained by subtracting the discharge of the San Carlos from that of the San Juan at Ochoa.]

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1898.				
January 10 to 31	23,270	19,500	21,030	917,650
February	34,900	18,500	22,080	1,226,260
March	22,000	14,600	16,850	1,036,070
April	25,800	12,900	15,120	899,700
May	19,200	11,700	14,130	868 820
June	39,200	13,000	22,410	1,333,500
July	43,100	26,200	32,720	2,011,870
August	38,400	23,000	26,170	1,609,130
September	41,300	22,800	29,210	1,738,120
October	37,600	24,700	29,320	1,802,820
November	70,500	26,800	36,460	2,169,520
December	41,800	26,300	31,570	1,941,160
The year	70,500	11,700	24,756	17,554,620
1899.				
January	38,900	26,300	31,800	1,955,300
February	28,200	23,100	25,180	1,398,430
March	23,100	19,600	21,540	1,324,450
April	20,880	15,388	17,575	1,045,777
May	16,740	13,390	14,981	920,979
June	30,580	13,540	17,229	1,025,231
July	38,030	17,000	25,777	1,586,005
August	35,900	21,050	26,253	1,614,281
September	56,900	21,250	27,472	1,634,741
October	29,320	20,910	25,548	1,471,747
November	41,720	21,460	28,959	1,723,175
December	32,710	23,450	26,706	1,642,110
The year	56,900	13,540	24,085	17,342,226
1900.				
January	26,854	19,640	21,994	1,352,370
February	19,832	16,597	18,292	1,025,925
March	16,633	13,520	15,133	930,495
April	13,620	11,122	12,186	725,127
May	22,750	10,188	12,569	772,860
June	22,060	11,144	16,524	983,237
July	34,730	17,554	24,496	1,406,242
August	59,082	23,770	33,946	2,087,339

Discharge of small tributaries of San Juan River above Boca San Carlos, 1899–1900.

Stream.	Discharge in second-feet.			Number of measurements.
	Maximum.	Minimum.	Mean.	
Melchora	287	0	78	10
Medio Queso	1,160	0	525	12
Palo de Arco	227	0	106	9
Caño Chico	540	0	242	8
Caño Negro	1,277	0	168	43
Los Sabalos	12,134	23	581	115
Poco Sal	2,651	34	1,120	17
Santa Cruz	10,301	36	881	17
Santa Crucita	623	0	287	3
Bartula	2,437	40	357	16
Infiernito	2,449	80	898	16
Machuca	573	27	161	17
La Crucita del Norte	108	0	32	6
La Crucita del Sur	152	0	95	4
La Cruz del Norte	293	0	96	13
La Cruz del Sur	77	0	38	2
El Jardin	742	25	166	23
La Tigre	560	17	88	22

Discharge of small tributaries of San Juan River below Boca San Carlos, 1899–1900.

Stream.	Discharge in second-feet.			Number of measurements.
	Maximum.	Minimum.	Mean.	
Cureña	1,145	43	394	17
Danta	355	24	140	17
Tambor Grande	111	9	43	10
San Geronimo	117	3	10	4
Tamborcito	661	17	302	14
Copalchi	769	17	233	15
Guasimo	234	13	66	16
Caño Maria	565	134	269	4
Sucio	100	4	31	8
La Tigre	894	41	368	16
San Juanillo (at mouth)	587	380	483	2

Estimated monthly discharge of Machado River.

[From triweekly observations.]

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1899.				
January	339	98	214	13, 178
February	150	68	97	5, 405
March	300	56	118	7, 252
April	213	60	101	6, 030
May	424	53	160	9, 854
June	251	95	159	9, 471
July	1, 035	170	337	20, 570
August	930	198	334	20, 747
September	1, 158	180	302	17, 994
October	225	100	154	9, 471
November	1, 252	79	309	18, 373
December	1, 464	110	338	20, 797
The year	1, 464	53	219	159, 142
1900.				
January	258	95	146	9, 011
February	311	73	120	6, 665
March	105	62	77	4, 740
April	83	37	55	3, 255
May	221	30	94	5, 796
June	196	79	112	6, 653
July	472	101	258	15, 862
August	989	209	528	32, 490
September	648	170	337	20, 025
October	355	80	169	10, 378
November	375	113	267	12, 327
December	2, 602	168	600	36, 538
The year	2, 602	30	230	163, 740

SAN FRANCISCO RIVER.

The most important stream that will be intercepted by a canal line from Boca San Carlos to San Juan del Norte, on the left bank of the San Juan, is the San Francisco. Its principal branch is the Chanchos. Above the Chanchos a smaller tributary is called Nicholson Creek. These tributaries and the San Francisco above their junction were measured in 1898. From these observations a summary of monthly

discharge of the San Francisco at its mouth was made for 1898, and is here given. The discharge measurements in 1899 and 1900 follow:

Estimated monthly discharge of San Francisco River at its mouth.

[Obtained by combining observations taken on the Upper San Francisco and Chanchos rivers and Nicholson Creek.]

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1898.				
January	1,270	230	583	35,850
February	1,360	170	489	27,160
March	390	120	199	12,240
April	1,260	110	254	15,110
May	560	125	232	14,260
June	1,100	115	373	22,200
July	1,890	270	684	42,060
August	800	185	364	22,380
September	1,280	150	382	22,730
October	510	130	274	16,850
November	1,520	100	502	29,870
December	1,090	160	398	24,470
The year	1,890	100	394	285,180

Discharge measurements made on San Francisco River.

Date.	Hydrographer.	Meter number.	Area of section.	Mean velocity.	Discharge.
1899.			*Square feet.*	*Ft. per sec.*	*Second-feet.*
Oct. 9	H. W. Durham	Price No. 34	491	0.52	256
Nov. 7	do	do	1,083	1.12	1,212
Nov. 28	do	do	834	0.30	247
1900.					
Jan. 24	H. G. Heisler	Price No. 63	662	0.64	429
Feb. 16	H. C. Hurd	Price No. 34	503	0.26	131
Mar. 18	do	do	415	0.36	148
Apr. 29	do	Price No. 35	270	0.10	27
May 21	H. G. Heisler	B. & B. No. 1	348	0.36	126
June 4	do	do	508	0.64	326
June 27	do	do	417	0.42	176
Aug. 1	do	do	810	0.57	465
Aug. 16	do	do	842	1.15	968
Aug. 30	do	do	978	1.21	1,187
Sept. 11	do	do	625	0.54	340
Sept. 24	do	do	751	0.73	554

SEDIMENT TRAP ON SARAPIQUI.

SARAPIQUI RIVER.

A station for the measurement of rainfall, sediment, and discharge on the Sarapiqui was maintained about 6 miles above the mouth of that river from August, 1898, to the end of the year 1899, and the record is complete for that period. A native observer took rainfall and gage-height observations throughout 1900, and approximate results for that year also are given.

Estimated monthly discharge of Sarapiqui River 5 miles above its mouth.

[Drainage area, 1,100 square miles, approximately.]

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1899.				
January	22,077	3,000	5,420	333,260
February	27,100	2,710	5,200	288,800
March	8,972	2,240	3,350	205,980
April	6,481	1,928	3,173	188,835
May	18,054	1,694	4,357	267,905
June	16,766	3,753	6,553	399,916
July	61,479	5,223	14,173	871,488
August	23,347	5,020	8,094	497,708
September	15,076	4,474	6,418	381,931
October	15,670	3,778	5,920	363,982
November	26,678	4,219	11,605	691,724
December	42,110	6,876	11,512	685,012
The year	61,479	1,694	7,150	5,176,541
1900.				
January	33,637	3,631	7,458	458,575
February	7,598	1,025	3,598	199,828
March	6,464	800	1,726	106,119
April	14,180	2,500	4,055	241,065
May	14,852	1,944	5,472	336,441
June	11,991	4,530	7,041	418,997
July	27,038	6,547	9,880	607,532
August	21,077	5,566	10,257	630,690
September	28,946	3,753	7,652	455,340
October	23,498	5,800	11,094	682,211
November	41,808	6,298	14,258	848,406
December	62,236	4,194	13,624	837,713
The year	62,236	800	8,043	5,822,917
1901.				
January	38,500	3,390	8,624	530,270
February	9,650	2,900	4,448	247,030

SAN JUANILLO RIVER.

Lull route, variants I, II, and III, all require that the San Juanillo River be diverted below the mouth of the Deseado River and conducted to the sea north of the canal line. To obtain data on this problem, a gage was established on that river January 1, 1900. Daily readings of the gage and occasional measurements of discharge were made, the results of which are as follows:

Estimated monthly discharge of San Juanillo River below the mouth of the Deseado.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1900.				
January	2,520	925	1,603	98,596
February	1,616	507	904	50,181
March	1,044	325	626	38,508
April	460	260	311	18,534
May	1,405	245	744	45,765
June	729	440	619	36,828
July	1,883	934	1,421	87,458
August	2,500	1,489	2,184	134,305
September	2,225	1,215	1,786	106,292
October	2,260	1,268	1,794	110,330
Total	2,520	245	1,211	726,797

DISTRIBUTARIES OF SAN JUAN RIVER.

The waters of the San Juan River have two principal outlets, the southern called the Colorado River, and the northern called the lower San Juan. The latter stream sends out two other distributaries which empty into the ocean between the two larger, and are called the Parado and Taura. It seems, however, that a portion of the course of the Taura is, during the season of low water, higher than the water in the San Juan, and it becomes a tributary of the latter. It was visited on May 6, 1898, and was at that time discharging 25 cubic feet per second into the San Juan. On the same day the discharge of the San Juan below the Taura was 1,112 cubic feet per second. The discharge at Ochoa on the same date was 16,950 cubic feet per second.

On July 13 the Taura was flowing away from the San Juan, and its volume 200 yards below its exit was 2,234 cubic feet per second. On this day the discharge of the San Juan at Ochoa was 46,000 cubic feet per second.

On March 19, 1900, the Taura was observed to be discharging 8

cubic feet per second, and on April 30, 1900, 3 cubic feet per second, into the San Juan.

The condition of the Taura flowing toward the San Juan is abnormal, its normal condition being that of a minor distributary of the San Juan.

Measurements of discharge of distributaries of San Juan River.

Stream.	Discharge in second-feet.			Number of measurements.
	Maximum.	Minimum.	Mean.	
San Juanillo	199	4	80	13
Colorado	39,034	22,336	30,685	2
Lower San Juan	22,337	559	5,721	10
Parado	265	34	124	11
Tauro	1,669	0	730	13

RAINFALL.

Observations of rainfall were made at each river station, the form of gage used at most of the stations being a metal funnel which caught the rain and discharged it into a bottle, from which it was measured in a graduate bearing a known relation to the diameter of the funnel. The gage was always placed in a position as exposed as possible, but nearly always this was a small clearing in the forest, which was still well sheltered from the wind.

One of the most remarkable characteristics of Nicaragua is its rainfall, and there are radical and striking differences in the climate of the east and west coasts with reference to it.

From the records it will be seen that there is no definite dry season on the eastern coast, but that rain may be expected any day in the year, and the expectation will seldom be disappointed.

On the Pacific coast, on the contrary, there is little rain from the beginning of January till the middle of May, when the rainy season begins, but the region is subject to violent downpours during the rainy season, the precipitation for a single day being often several inches. Mr. William Climie reports a rainfall of 9 inches in nine hours at Nandaime, a small town south of Granada.

No less remarkable is the excessive aggregate of rainfall in a limited district of which the nucleus seems to be in the vicinity of San Juan del Norte. The annual precipitation at this point, as deduced from the mean of six years' observation, is about 260 inches, while that at Bluefields, 73 miles north also on the Caribbean, is only about 105; that of Port Limon, an equal distance south, is 118; that of Colon, the Caribbean end of the Panama Canal, is 124, and that of Ochoa, 54 miles west of San Juan del Norte, is 168. A short record at Lake

Silico, near San Juan del Norte, seems to show a still heavier rainfall, and from this neighborhood the precipitation seems to decrease in all directions.

The heaviest fall of rain observed in Nicaragua was reported by Mr. Howard Scharschmidt, at Silico station on Lake Silico, November 4, 1899, 10.5 inches in six hours, or an average of 1¾ inches per hour. On the same date, Mr. Charles D. Scott, at San Juan del Norte, observed 12.48 inches in twenty-four hours, of which 8 inches fell in about six hours. These are the heaviest falls for a single day yet observed. The heaviest monthly rainfall observed on the Isthmus by the Commission was at San Juan del Norte for November, 1900—55.38 inches.

Rainfall at San Juan del Norte, Nicaragua, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1890....	26.80	6.36	5.93	18.11	4.93	46.84	52.55	35.72	8.14	24.86	25.55	41.65	296.94
1891....	20.30	2.57	1.95	10.40	13.78	26.95	23.57	19.49	14.16	20.21	28.15	32.74	214.27
1892....	28.57	11.38	4.98	18.38	50.88	13.42	38.96	23.63	11.47	27.95	36.93	24.65	291.20
1893....	17.70	7.53	3.93	9.99	2.77	......	......	......	......	......	......	......	......
1898....	19.44	25.17	10.16	7.82	9.37	19.52	24.63	16.38	7.24	12.50	32.35	17.06	201.64
1899....	23.49	11.69	8.33	9.09	21.24	20.97	39.62	29.50	36.95	12.44	40.36	32.25	285.93
1900....	21.20	10.72	7.47	4.62	22.06	11.43	27.13	38.96	26.45	22.44	55.38	18.24	266.10
Mean..	22.50	10.77	6.11	11.20	17.86	23.19	34.41	27.28	17.40	19.98	36.45	27.76	259.35

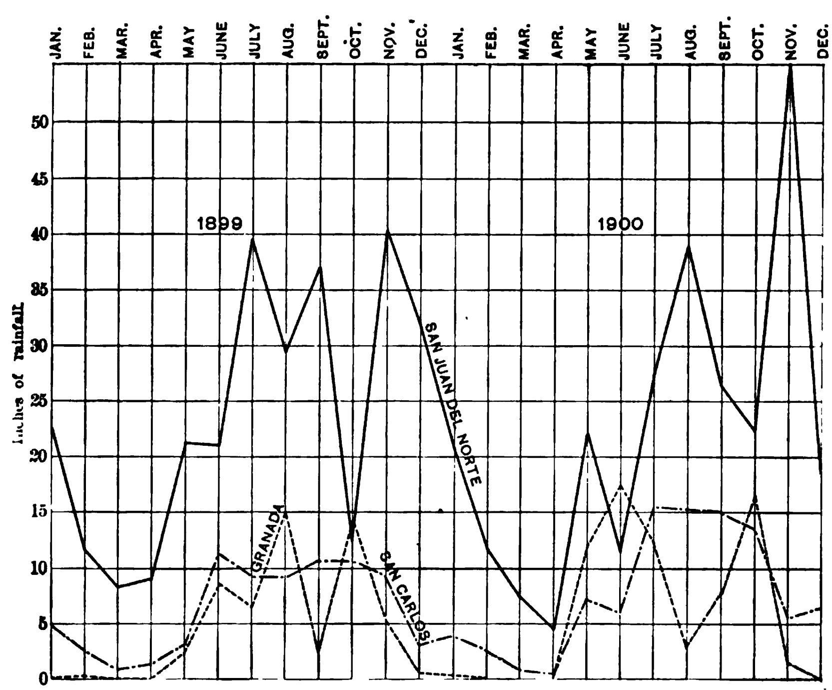


FIG. 229.—Comparative rainfall at San Juan del Norte, San Carlos, and Granada.

Rainfall at San Antonio plantation, in inches.

[Latitude, 12° 32′ N. Longitude, 86° 59′ W. Elevation, 66 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1895....	0.00	0.00	0.00	....	7.98	6.29	3.36	5.07	21.68	21.71	3.42	0.32	69.83
1896....	0.00	0.00	0.00	0.20	12.20	10.50	7.54	4.71	13.39	11.22	4.76	0.98	65.50
1897....	0.00	0.00	1.26	0.59	18.23	14.53	6.81	13.86	10.94	31.06	0.98	0.00	98.26
1898....	0.24	0.00	0.00	0.00	16.00	11.60	8.37	14.85	16.71	7.60	5.64	0.04	81.05
1899....	0.00	0.44	0.00	0.00	2.12	9.82	8.08	9.60	5.50	26.85	4.81	0.00	67.22
1900....	0.00	0.00	0.55	1.02	6.05	22.46	18.81	6.80	13.69	24.45	1.85	0.00	95.68

Rainfall at Valle Menier, in inches.

[Latitude, 11° 46′ N. Longitude, 85° 57′ W. Elevation, 492 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1880....	0.00	0.00	0.00	0.00	13.48	9.92	2.24	9.96	6.77	13.46	2.72	0.00	58.55
1881....	0.55	0.00	0.00	0.00	9.94	12.88	7.52	8.86	9.10	22.68	9.33	0.98	81.84
1882....	0.00	0.00	0.00	0.00	1.93	12.87		6.30	4.92	19.13	2.76	0.00	47.91
1883....	0.00	0.00	0.00	0.00	1.35	7.44	3.94	....	....	....	....	....	....
1899....	0.00	0.00	0.00	0.00	....	....	....	....	2.04	15.95	6.11	0.00	....
1900....	0.00	0.00	0.00	0.31	10.36	11.00	9.94	44.64	17.46	11.54	....	....	....

Rainfall at Managua, in inches.

[Latitude, 12° 7′ N. Longitude, 86° 16′ W. Elevation, 148 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1891....	0.00	0.00	0.00	0.00	1.08	14.00	5.04	3.04	8.43	9.64	7.24	0.43	48.90
1892....	0.00	0.00	0.00	0.00	8.58	11.34	6.35	7.98	9.24	20.55	3.09	....	67.13
1899....	....	....	....	....	....	....	....	....	2.21	18.59	2.79	0.11	....
1900....	0.00	0.00	0.00	0.00	6.62	8.54	7.97	3.83	7.57	17.48	1.37	0.17	58.55

Rainfall in Nicaragua and Costa Rica in 1898, in inches.

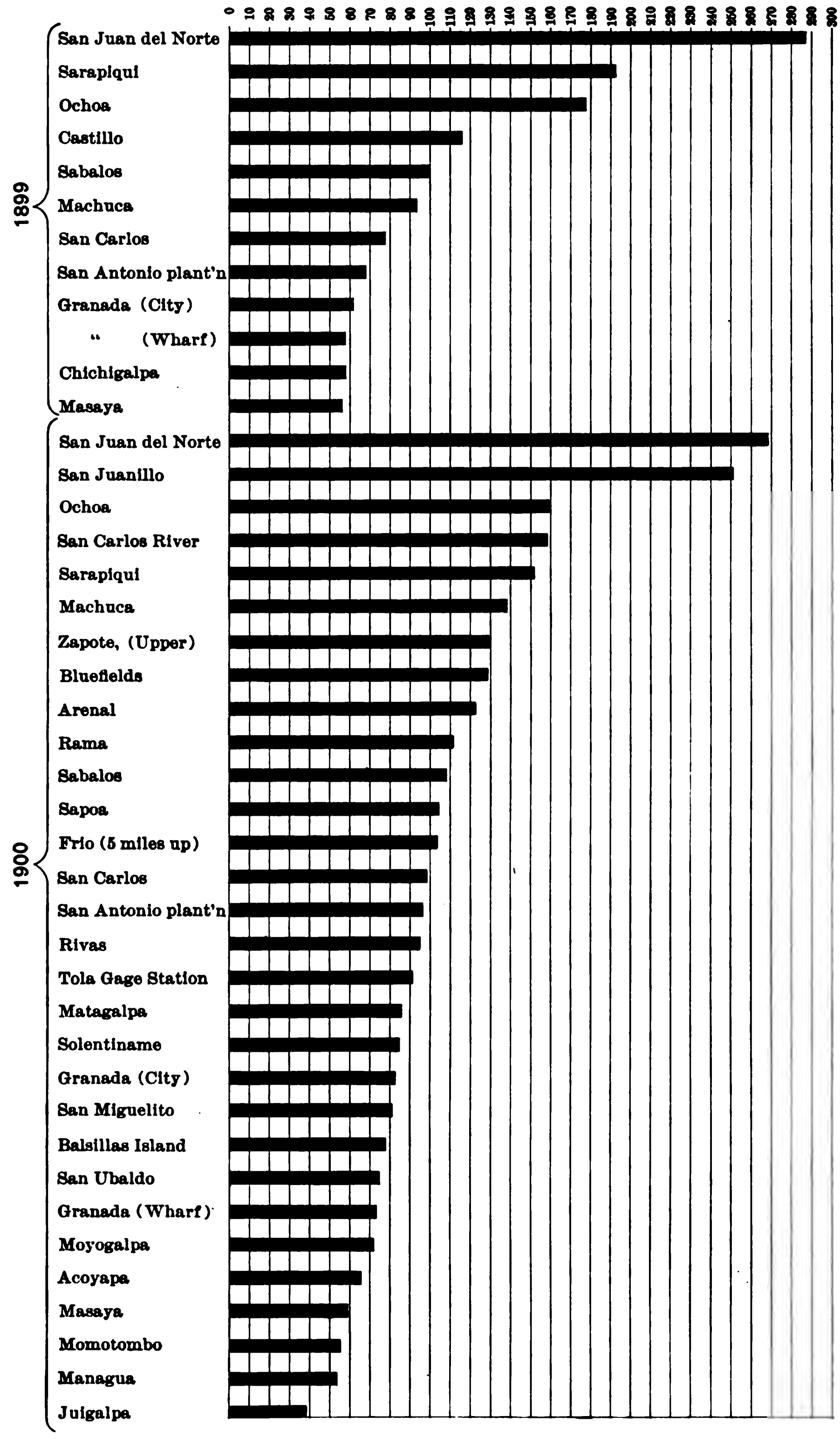
Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Brito and Tola	0.25	0.00	0.08	0.08	11.30	14.86	11.42	6.17	16.60	25.70	6.01	2.41	94.88
Rivas..............	1.07	0.12	0.10	0.00	16.17	18.95	13.65	11.85	13.99	20.83	8.19	3.14	108.06
Las Lajas..........	0.25	0.05	1.34	0.28	10.60	13.50	10.64	8.44	6.79	16.19	4.41	2.26	74.75
Rio Viejo..........	......	0.01	0.66	0.00	13.78	13.45	4.01	11.66	7.28	8.99	0.61	0.17	60.62
Tipitapa...........	......	0.00	0.26	0 00	8.56	16.88	6.24	7.82	11.25	7.12	0.93	0.17	59.23
Morrito............	......	......	......	0.07	8.92	14.05	13.84	10.20	......	......	......	......	....
Fort San Carlos....	......	......	1.21	3.00	8.22	15.56	13.35	8.00	10.56	8.93	9.86	5.62	84.31
Sabalos............	......	......	2.10	6.00	11.69	17.13	20.69	11.83	11.42	11.81	12.17	10.20	114.54
Castillo...........	......	......	......	......	......	......	18.92	11.46	16.22	4.64	14.04	11.64	....
Machuca	......	......	......	......	......	......	......	6.52	12.86	9.83	15.65	6.75	....
Rio San Carlos.....	......	......	7.52	11.66	20.12	20.79	18.26	11.68	......	......	......	......	....
Ochoa	13.07	14.08	8.04	12.23	15.25	21.47	21.60	12.08	15.12	8.02	21.50	8.38	170.84
San Francisco [a]....	15.33	18.43	8.72	11.25	13.87	18.87	19.22	13.45	10.95	9.09	22.28	10.61	172.17
Sarapiqui..........	......	......	......	......	......	......	......	......	11.19	11.35	18.63	7.12	....
Deseado [b]..........	21.92	26.98	11.76	8.83	14.84	18.66	26.86	13.31	5.23	11.92	29.25	21.07	210.68
Greytown	19.44	25.17	10.16	7.82	9.37	19.52	24.68	16.38	7.24	12.50	32.35	17.06	201.64

[a] Record incomplete from January 1-5, inclusive, and from December 29-31, inclusive, so the rainfall at Ochoa for those days is added.

[b] Rainfall not observed from December 25-31, 1898; so the record was completed by including the corresponding days of 1897.

Rainfall in Nicaragua and Costa Rica during 1899, in inches.

Location.	Observer.	Total inches.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Established.
Acoyapa	Modesto Cuadra									9.60	3.30	15.32	8.95	1.20	Aug. 10
Balsillas	Sherwood Wilson										0.49	5.95	9.22	1.96	Sept. 26
Bluefields	T. W. Waters									2.18	29.11	8.10	9.55	9.75	Aug. 26
Castillo	John Augustine	114.50	10.32	6.47	2.02	2.21	5.90	9.29	18.11	17.73	12.01	8.21	15.33	6.90	
Chichigalpa	S. H. Young	58.20	0.00	0.00	0.00	0.60	0.88	4.56	5.13	6.88	4.06	32.29	3.80	0.00	
Colorado	H. Scharschmidt			10.72	11.83	13.17	19.11		43.99	29.78		11.92			
Frio River	Sherwood Wilson											0.90	8.36	3.53	Oct. 21
Granada	S. Vargas	56.93	0.00	0.52	0.11	0.02	2.43	8.78	6.64	15.41	2.39	14.79	5.24	0.57	Jan. 25
Granada	Nicaragua sugar estates	60.33	0.36	0.43	0.00	0.00	2.48	10.19	7.47	14.77	3.78	15.13	4.85	0.87	
Indio (Negro)	S. H. Harris											0.25	18.55	18.65	Oct. 27
Javali Mine	W. H. S. Grigsby										5.60	8.81	7.65	4.78	Sept. 17
Juigalpa	J. J. Sequeira									4.25	0.83	12.97	10.26	0.60	Aug. 19
La Libertad	Pelayo Porto									7.05	2.85	8.33	9.12	5.46	Aug. 16
Machuca	A. Faris	93.08	12.96	4.61	1.65	5.61	7.08	8.58	18.33	18.79	5.69	1.91	4.09	3.78	
Managua	T. Bird										2.21	18.59	2.79	0.11	Sept. 16
Masaya	J. Weist	45.24	0.50	0.48	0.07	0.00	2.02	8.62	4.19	9.47	2.80	10.35	5.54	1.20	
Matagalpa	W. K. Henley										1.43	15.88	5.29	1.18	Sept. 12
Momotombo	A. Peterson										0.97	26.55	5.30	0.62	Sept. 16
Moyogalpa	K. B. Luna										3.08	18.32	5.99	7.03	Sept. 1
Ochoa	H. S. Reed	176.91	14.02	7.96	5.80	7.09	12.60	15.69	30.20	17.50	15.49	7.85	20.58	22.13	
Pinon	Fernando Loredo										4.94	9.11	5.24	2.02	Sept. 13
Rama	T. W. White									2.65	11.58	10.90	13.42	8.33	Aug. 18
Rivas	Earl Flint	67.82	0.85	1.70	0.65	0.00	1.62	7.53	10.69	9.26	5.15	20.39	9.06	0.92	
Rivas	J. O. Jones												5.91	0.57	Nov. 7
Sabalos	R. H. Morrin	98.55	9.82	4.33	2.73	2.65	5.50	11.31	15.87	12.15	14.70	6.67	8.09	4.73	
San Antonio Plantation	Nicaragua sugar estates	67.22	0.00	0.44	0.00	0.00	2.12	9.82	8.08	9.60	5.50	26.85	4.81	0.00	
San Carlos	E. Humphreys	77.20	4.99	2.79	1.05	1.48	3.18	11.24	9.28	9.23	10.67	10.66	9.43	3.20	
San Carlos River	H. S. Reed											6.03	20.32	18.03	Oct. 12
San Francisco	T. Merriman										0.82	1.60	6.82	3.00	Sept. 23
San Juan del Norte	Chas. D. Scott	285.93	23.49	11.69	8.33	9.09	21.24	20.97	39.62	29.50	36.95	12.44	40.36	32.25	*
San Miguelito	J. F. Cuadra											8.13	6.95	2.78	Oct. 5



COMPARATIVE RAINFALL AT STATIONS IN NICARAGUA AND COSTA RICA.

Rainfall in Nicaragua and Costa Rica during 1899, in inches—Continued.

Location.	Observer.	Total inches.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Established.
San Ubaldo	Frank Trap							1.80	4.30	9.45	6.22	11.10	9.31	1.87	June 21
Sapoa	M. C. Hogan								5.42	8.74	5.34	6.45	8.59	1.98	July 16
Sarapiqui	T. F. Boltz et al	190.40	16.57	7.77	5.67	9.13	14.78	12.90	24.89	21.05	17.05	10.55	29.29	20.75	
Sardinas	T. Montiel												11.59	1.71	Nov. 1
Sucia (Boca)											13.72	13.95	30.32	19.88	Sept. 17
Tipitapa	F. Davis et al		0.26							2.22	2.57	11.69	5.42	0.44	[a]
Tola Gage Station	J. O. Jones									4.81	3.35	29.49	5.48	0.52	Aug. 13
Valle Menier	V. Gavinet										2.04	15.95	6.11	0.00	Sept. 2
Viejo	Fred Davis									1.39	2.27	16.91	2.29	0.08	Aug. 18
Zapote	J. G. Kennedy								12.33	11.63	9.45	8.04	16.23	6.18	July 3
Zapote	G. B. Zampieri											10.57	14.78	7.09	Oct. 3

[a] Discontinued January 24; reestablished August 20.

Rainfall in Nicaragua and Costa Rica during 1900, in inches.

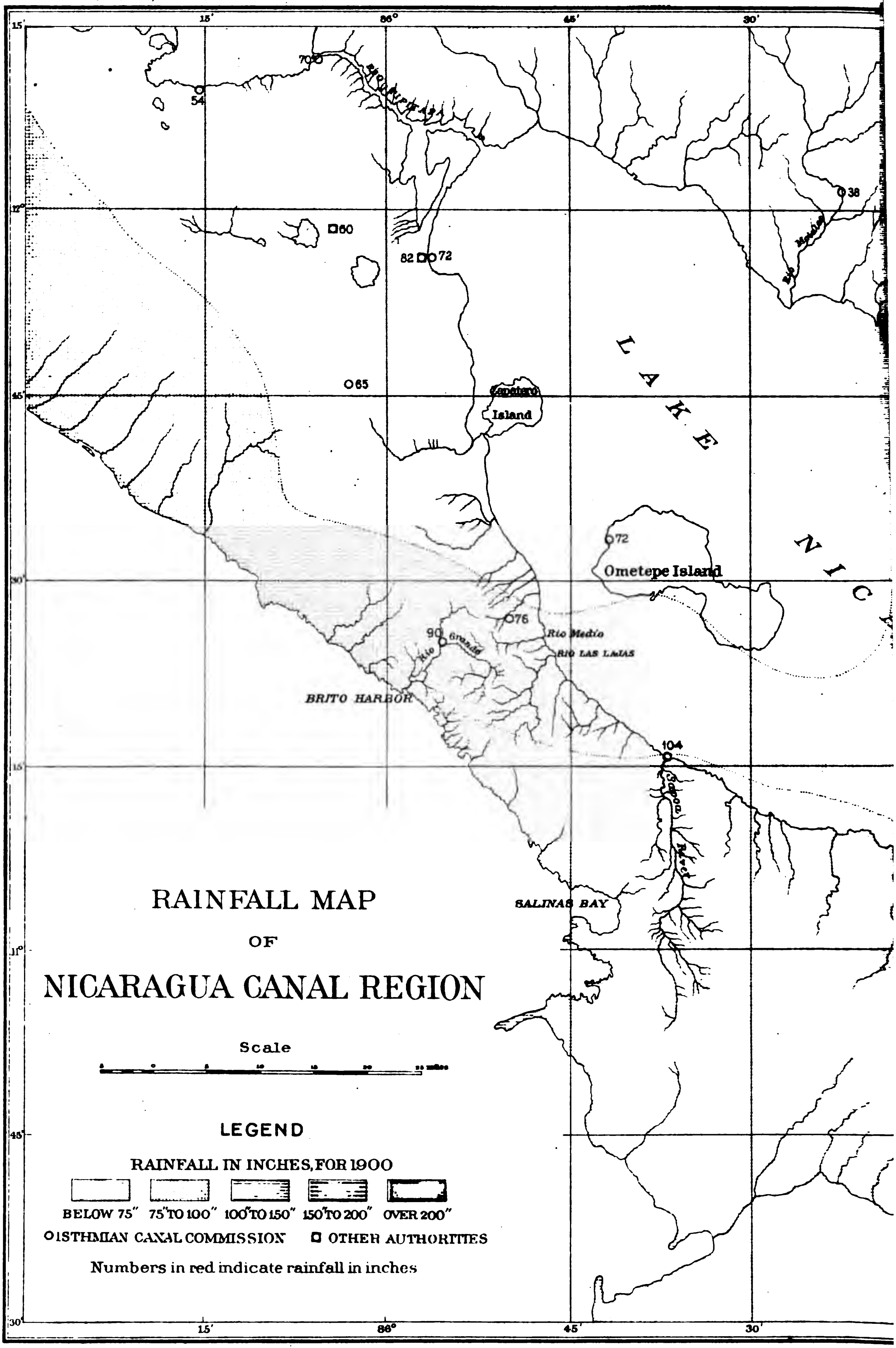
Location.	Observer.	Total.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Acoyapa, Nicaragua	Modesto Cuadra	65.04	0.58	0.21	0.22	0.16	11.31	10.19	12.91	4.76	9.36	12.96	1.12	1.26
Arenal, Costa Rica[a]	Godfrey Hahn	121.70	4.45	2.73	3.18	4.25	17.35	7.11	15.96	13.71	15.42	11.61	13.64	12.30
Basillas Island, Nicaragua	S. Wilson et al	77.10	1.78	1.04	0.52	0.34	9.54	4.49	10.67	14.05	12.48	14.45	2.97	4.77
Boca Sucia, Costa Rica			9.65	0.80										
Bluefields, Costa Rica	Thomas W. Waters	127.63	5.70	6.95	3.55	1.05	10.40	8.90	14.60	23.55	11.20	12.32	14.90	14.51
Castillo, Costa Rica	John Augustine			4.37	2.22	2.32	18.04	9.82	18.42	33.83	15.24	21.38	6.86	16.98
Frio (5 miles up), Costa Rica	Fred Davis	102.66	3.17	2.31	0.92	0.75	13.61	11.68	13.29	12.21	11.76	20.15	6.19	6.62
Granada Wharf, Nicaragua	Stephen Vargas	72.10	0.26	0.00	0.03	0.02	12.06	17.63	12.40	3.93	7.60	16.70	1.42	0.05
Granada City, Nicãragua	Nicaragua sugar estates	82.46	0.45	0.00	0.00	0.10	16.01	19.74	13.40	5.58	9.46	15.90	1.60	0.22
Juigalpa, Nicaragua	J. Jesus Sequeira	37.73	0.05	0.12	0.18	0.22	6.49	2.05	3.42	3.77	9.79	10.56	0.63	0.45
Las Haciendas, Nicaragua	R. de Hennin						8.95	7.58	16.45	12.05	20.61	22.14	5.58	
Machuca, Nicaragua	J. S. Martinez et al	137.88	1.37	1.67	2.05	2.39	17.70	7.46	22.65	25.80	18.20	10.68	12.35	15.56

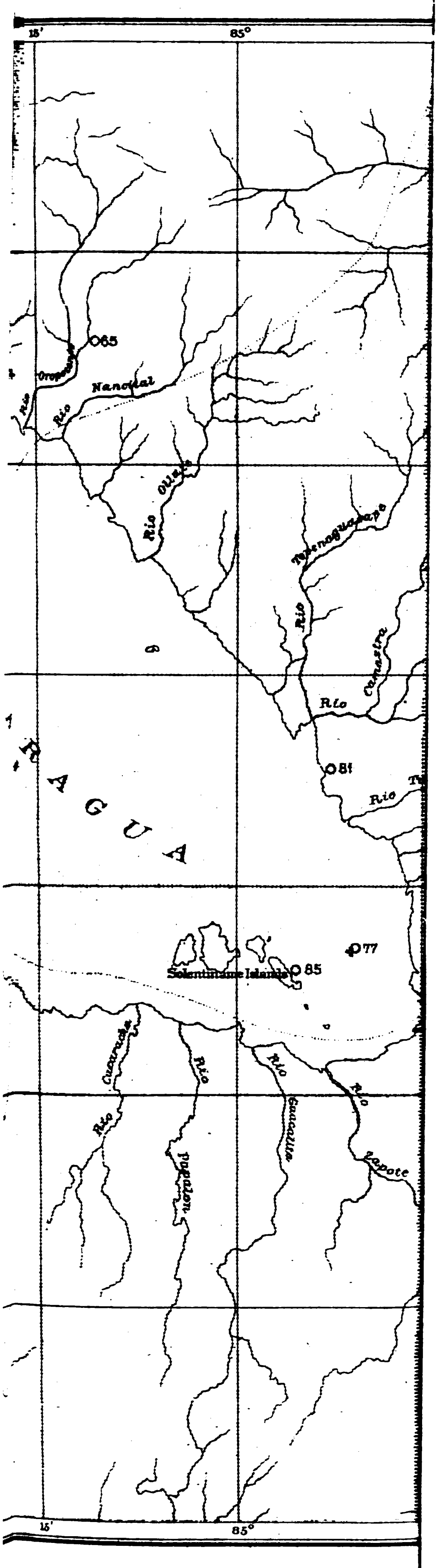
[a] Upper San Carlos River.

Rainfall in Nicaragua and Costa Rica during 1900, in inches—Continued.

Location.	Observer.	Total.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Managua, Nicaragua	T. Bird	53.55	0.00	0.00	0.00	0.00	6.62	8.54	7.97	3.83	7.57	17.48	1.37	0.17
Masaya, Nicaragua	J. Wiest	59.70	0.00	0.00	0.00	0.00	8.66	15.52	10.27	4.70	7.23	11.24	1.91	(17)
Matágalpa, Nicaragua	W. K. Henley et al	85.68	0.24	0.36	0.87	1.09	16.06	14.49	13.13	5.12	10.40	17.35	4.27	2.30
Momotombo, Nicaragua	A. Peterson	55.21	0.00	0.00	0.00	0.00	6.67	13.48	6.96	0.90	5.63	18.78	2.06	0.73
Moyogalpa, Nicaragua	K. B. Luna	71.70	0.13	0.03	0.22	0.05	13.59	11.46	8.28	7.95	12.44	15.63	1.58	0.34
Negro (Indio), Nicaragua	S. H. Harris	....	12.32	12.69	5.50	2.51	18.13	10.41	12.67	40.15	12.85	....	....	....
Ochoa, Costa Rica	H. S. Reed	158.83	9.12	4.49	7.58	4.29	13.36	11.24	16.45	26.46	16.66	8.53	15.69	24.96
Palo Seco, Costa Rica [a]	A. Quintania	....	....	4.37	5.47	3.62	16.01	13.98	15.15	24.96	18.34	11.18	18.12	25.80
Rama, Nicaragua	G. W. White et al	110.35	2.52	3.31	3.20	1.48	12.70	6.73	16.30	19.56	19.58	10.97	7.61	6.39
Rivas, Nicaragua	Earl Flint	94.68	0.19	0.02	0.11	0.02	11.19	16.38	10.61	9.16	22.58	21.93	1.18	1.31
Rivas, Nicaragua [b]	Charles Hayman	....	....	....	....	....	....	5.07	6.93	6.82	16.86	18.12	0.87	0.62
Sabalos, Nicaragua	Thomas F. Boltz	107.34	3.19	3.84	1.69	0.64	8.57	8.37	16.89	20.40	11.24	16.34	6.72	9.45
San Antonio Plantation, Nicaragua	....	95.68	0.00	0.00	0.55	1.02	6.05	22.46	18.81	6.80	13.69	24.45	1.85	0.00
San Carlos River, Costa Rica	H. S. Reed	157.30	8.79	4.96	6.56	3.00	15.42	11.26	15.53	22.72	21.36	6.45	16.56	24.69
San Carlos, Nicaragua	Fred Davis et al	98.34	3.09	2.66	0.81	0.41	14.19	6.04	15.44	15.29	15.02	13.59	5.42	6.38
San Juan del Norte, Nicaragua	Charles D. Scott	266.10	21.20	10.72	7.47	4.62	22.06	11.43	27.13	38.96	26.45	22.44	55.38	18.24
San Juanillo, Nicaragua	Fred Appleby	249.20	18.79	11.79	7.18	2.28	17.18	6.53	22.66	41.01	28.18	24.84	43.34	25.42
San Miguelito, Nicaragua	J. F. Cuadra	81.11	1.38	1.02	0.49	1.40	13.58	10.19	15.83	8.46	7.20	13.41	4.71	3.44
San Ubaldo, Nicaragua	G. C. W. Magruder	74.26	1.22	0.19	0.27	0.09	7.44	9.85	24.91	5.32	14.08	8.91	1.43	0.55
Sapoa, Nicaragua [c]	M. C. Hogan	103.60	1.11	0.57	0.63	0.54	10.21	12.85	14.74	10.70	23.75	22.28	3.91	2.31
Silico, Nicaragua [d]	E. A. Keys	....	....	....	1.08	2.69	15.81	8.72	6.28	....	....	....	....	....
Sarapiqui, Costa Rica	Paulino Gonzalez	151.48	9.65	5.00	10.76	2.63	10.54	9.84	22.24	23.48	6.99	11.08	24.86	24.86
Sardinas, Nicaragua	Tomas Montiel	....	1.89	2.73	0.61	0.20	....	....	....	....	....	....	....	....
Solentiname, Nicaragua [e]	J. M. Boniche	84.68	1.66	1.95	1.10	1.40	12.47	5.31	8.63	14.21	15.43	14.89	4.04	3.59
Tipitapa, Nicaragua [f]	L. Roy Cannon	....	0.00	0.02	0.00	0.15	13.53	12.60	12.58	6.04	8.32	15.00	....	....
Tola Gage Station, Nicaragua	J. O. Jones	90.04	0.17	0.00	0.01	0.33	12.91	12.29	15.67	4.53	24.15	18.46	0.87	0.65
Valle Menier, Nicaragua	V. Gavinet (Nandaime)	....	0.00	0.00	0.00	0.31	10.36	11.00	9.94	4.64	11.54	17.46	....	....
Zapote (Upper), Costa Rica	G. B. Zampieri	128.64	4.09	2.62	2.29	1.44	12.13	7.11	17.55	14.50	23.93	18.22	13.43	11.33

[a] Established February 7.
[b] Established June 15.
[c] Removed to Tortuga July 16.
[d] Established March 22; discontinued July 9.
[e] Isla Venado, Lake Nicaragua.
[f] Discontinued October 30.


RAINFALL MAP
OF
NICARAGUA CANAL REGION
Scale
LEGEND
RAINFALL IN INCHES, FOR 1900
BELOW 75" 75" TO 100" 100" TO 150" 150" TO 200" OVER 200"
ISTHMIAN CANAL COMMISSION
OTHER AUTHORITIES
Numbers in red indicate rainfall in inches
LAKE NIC
Zapatera Island
Ometepe Island
Rio Medio
RIO LAS LAJAS
Rio Grande
BRITO HARBOR
SALINAS BAY
Sapoa River
15'
86°
45'
30'
54
70
60
82
72
65
38
76
90
104


15'
85°
O65
Rio Oropeso
Rio Nanocual
Rio Ollats
Rio Tepenaguasapo
Rio
Camastra
Rio
O81
Rio
A G U A
O77
O85
Solentiname Islands
Rio Cuacrache
Rio
Pepalon
Rio
Guacalito
Rio
Zapote
15'
85°

Rainfall in Nicaragua and Costa Rica in 1901, in inches.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Fort San Carlos	2.59	0.99	1.31	0.93							
Granada	0.00	0.00	0.00	0.00	1.14	14.67	13.36	13.96	15.62	12.84	0.45
Ochoa	10.25	2.61	5.26	5.57							
San Juan del Norte	29.92	4.32	6.47	11.06	3.52	14.69	18.54	18.36	5.46	38.89	4.81
San Ubaldo	0.45	0.02	0.12	0.00							
Tortuga	1.38	0.10	0.20	0.14							
Solentiname Island	2.00	0.83									

Rainfall at Granada, Nicaragua, in inches.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1876					5.77	13.65	26.61	4.96					
1877	0.00	0.00	0.00	0.00	11.57	10.24	10.12	5.32	17.36	5.27	0.87	0.59	61.34
1883	0.35	0.00	0.00	0.18	0.28	5.20	2.66	5.47	9.74	19.91	3.64	0.00	47.43
1884	0.00	0.00	0.00	0.00	0.00	8.25	3.99	3.75	8.82	8.63	2.28	0.26	35.98
1897	0.00	0.00	0.97	1.77	16.63	30.79	8.88	10.87	10.21	11.97	1.25	0.28	93.62
1898	1.07	0.00	0.02	0.00	12.82	10.44	6.09	7.30	5.25	10.49	1.87	0.24	55.59
1899	0.00	0.52	0.11	0.02	2.43	8.78	6.64	15.44	2.39	14.79	5.24	0.57	56.93
1900	0.26	0.00	0.03	0.02	12.06	17.43	12.40	3.93	7.60	16.70	1.42	0.22	72.07
1901	0.00	0.00	0.00	0.00	1.14	14.67	13.36	13.96	15.62	12.84	0.45	0.00	72.04
Mean	0.21	0.07	0.14	0.25	6.97	13.27	10.08	7.89	9.62	12.57	2.13	0.27	63.47

1876, Ramon Espinola; 1877, Dr. Earl Flint; 1883-4, National Institute; 1897-98, William Climie; 1899-1900, Stephen Vargas; 1901, Nicaragua Sugar Estates, Limited.

EVAPORATION.

The observation of evaporation by means of pans floating in the water was carried on under both the Nicaragua and Isthmian Canal commissions.

The inherent obstacles to accurate work by this method are great at all times, and, as might be expected, results are rather discordant. They are summarized in the tables following:

Monthly evaporation of Lake Nicaragua, in inches.

1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
San Ubaldo				6.42	6.26	5.19	5.08	4.87				
Las Lajas			5.77	8.13	5.98	4.35	3.38	3.41	2.73	2.73	3.00	3.01
Fort San Carlos			4.74	4.92	4.56	4.20	3.84	3.69	3.54	4.09	3.39	4.08
Mean			5.25	6.49	5.60	4.58	4.10	3.99	3.13	3.41	3.20	3.52

1899.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Las Lajas	3.40	3.39	4.25									
Fort San Carlos	3.72	3.28	4.34	5.01	4.65	3.60			2.02	2.85	2.23	2.70
San Ubaldo							3.87	3.87	3.78	4.40	3.72	3.71
Sapoa										3.56	3.24	3.91
Tipitapa									5.58	5.42	3.97	5.79
Mean									3.79	4.06	3.29	4.03

Monthly evaporation of Lake Nicaragua—Continued.

1900.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
San Carlos	2.89	3.16	4.36	4.62	4.34	3.93	2.63	2.24	3.24	2.35	3.39	3.04
San Ubaldo	4.57	4.24	5.47	5.79	7.59	4.95	5.46	5.05	4.74	4.64	3.90	4.03
Sapoa	4.36	5.40	6.33	6.41	5.12	3.19	2.54	2.30	3.36	......	......	......
Tipitapa	3.28	4.02	5.89	6.66	7.28	5.16	4.49	4.25	4.89	5.18	......	......
Mean	3.78	4.21	5.61	5.87	6.08	4.31	3.78	3.46	4.06	4.06	3.64	3.53

Allowance must be made in the use of these results for the fact that the conditions prevalent on the lake can not be duplicated in the evaporating pan. During the greater part of the year the trade winds blow strongly from the eastern side of the lake to the western. Except along the eastern shore the surface of the lake is blown into billows, the waves often attaining a considerable height and being crowned with whitecaps, and the total water surface in contact with the wind is much greater than the level surface of the lake. Most of the lake surface must therefore lose by evaporation a greater depth of water than the pan. The amount of evaporation during the dry season was obtainable by another method. The fluctuations of the lake were observed, and by applying to this the observations of rainfall upon the lake, the inflow from streams, and the discharge of San Juan River, the evaporation actually taking place upon the lake was obtained. During April, 1898, the evaporation was found by this method to be 6.12 inches. The results for 1900 and 1901 are given in the following table:

Evaporation from Lake Nicaragua.

[Evaporation = fall of lake + rainfall + inflow − outflow.]

Month.	Fall of lake, feet.	Rainfall on surface of lake, feet.	Inflow, feet.	Total, feet.	Outflow, feet.	Evaporation.		Inches, per day.
						Feet.	Inches.	
1900.								
February	0.71	0.08	0.14	0.93	0.44	0.49	5.88	0.21
March	0.83	0.04	0.10	0.97	0.40	0.57	6.84	0.22
April	0.70	0.04	0.07	0.81	0.35	0.46	5.52	0.18
May 1 to 15	0.32	0.08	0.03	0.43	0.17	0.26	3.12	0.21
1901.								
February	0.69	0.03	0.14	0.86	0.58	0.28	3.36	0.12
March	0.77	0.03	0.10	0.90	0.56	0.34	4.08	0.13
April	1.00	0.02	0.07	1.09	0.44	0.65	7.80	0.26

Area of lake, 1,904,000 acres.

Rainfall on surface of lake is an average of the rainfall at Basillas, Granada, Mayogalpa, San Carlos, San Miguelito, San Ubaldo, Sapoa, and Solentiname.

REGULATION OF LAKE NICARAGUA.

Lake Nicaragua being the summit level upon which the water supply for the canal depends, and from which the surplus water must be discharged, its history, and especially the extreme variations of its supply, are important. Its fluctuation depends upon four factors:

1. The inflow, which is a function of the amount and character of rainfall in the basin.
2. The storage capacity of the lake.
3. The evaporation, which varies with the seasons.
4. The outflow, which varies with the elevation of the lake.

The problem of the storage capacity is simple, and its solution is known with all desirable accuracy. The area of the lake is 2,975 square miles, or 1,904,000 acres.

The evaporation from the lake has been fairly well determined and can be allowed for without important error. It is given in the table, page 579–580.

The outflow was observed during 1898, 1899, and 1900, at Camp Farina, above Sabalos River, which is the first important tributary to the river.

The inflow has been observed by noting the fluctuation of the lake surface at four stations, San Carlos, San Ubaldo, Granada, and Sapoa. The fluctuation, after allowing for evaporation and outflow, gives the inflow.

It has not been possible to fix with certainty the limits of the natural fluctuation of Lake Nicaragua, but the best information obtainable indicates that the range is about 14 feet, from 97 as the minimum to 111 as the maximum.

The maximum stage was estimated as follows:

All the oldest inhabitants in the vicinity of the lake agree that a stage attained in 1861 was higher than any since reached. No more definite statement could be established than that it was "nearly up to the top of the wharf at Granada." The top of the wharf in the lowest place is at elevation 111.24 feet above sea level. If the mean lake level was within 6 inches of the top of the wharf during the customary breeze in that region, it is probable that the waves would wash over the wharf and the report would be that the water was over the top of the wharf. It is thought that the facts indicate 111 as about the elevation of the stage reported as nearly as it can be determined.

The low-water limit of 97 feet is taken on the information of Mr. William Climie, who testifies that the lake was lower in 1886 than it has been since, and all obtainable evidence on the subject is to the effect that no lower stage has occurred within the memory of persons now living.

All available testimony, and especially that of the engineman on the steamer *Victoria*, who has been in continuous service for sixteen years, is to the effect that the steamer *Victoria* has in that period always been able to discharge her cargo directly upon the wharf, but at times of extreme low water, occurring at very rare intervals, she could not come alongside, but had to lie off the end of the wharf, touching only her bow. This was the condition in May, 1897. A diagram of the wharf was made when the water stood at 5.8 reading on the gage rod, or 104.24 feet above sea level. It shows the bottom of the lake to be at an elevation of about 93 feet near the end of the wharf, and somewhat lower, say 92 feet, off the end where the steamer lay at low water. The boat draws from 4 feet of water when empty to 7 feet when fully loaded. Allowing her 6 feet of water in May, 1897, the stage of the lake was about 98 feet above sea level, or at least it could not have been lower than this.

If the lake were 1 foot lower than this in 1886, it would give a stage of 97, and this is probably near the true minimum.

These data fix the natural limit of fluctuation at 14 feet, though no fluctuation approaching this amount occurs in any one year, nor even in any two. The low water of 1886 was preceded by three successive years of low rainfall, as shown by the Granada record for 1883 and 1884 and by the Rivas record for 1885, the latter being the lowest in the Rivas record of twenty years with one exception. A study of the rainfall tables indicates another stage of extremely low lake just before the rainy season of 1897, this being preceded by three years of less than normal rainfall. This indication is confirmed by popular reports of an extremely low lake level at that time, and accounts for the fact that the heaviest rainfall of the record, 1897, did not produce as high a lake as had occurred in other years. Though no observations of the lake were made in 1897, those of 1898, considered with the rainfall record of 1897, indicate that the lake did not reach stage 107. (See diagram, fig. 230.) Its stage at the end of 1897 is known to have been about 105 by observations of the Nicaragua Canal Commission.

Judging from the table of rainfall, considered in the light of known facts, the lake has passed through minimum stages in May of the years 1886, 1891, and 1897; and maximum in the autumns of 1889, 1893, and 1900. None of these stages are exactly known except that of 1900, in which year the lake reached a maximum stage of 107.42 feet on the 27th day of October, and maintained about the same elevation for one week.

In this discussion we are concerned mainly with the years of maximum and minimum rainfall as giving the extreme conditions under which Lake Nicaragua must be controlled. All the records and traditions at hand indicate that the year 1897 was the year of greatest precipitation in this vicinity ever recorded. Dr. Flint gives for Rivas

a total for that year 123.43 inches, a rainfall of over 15 inches greater than any other in his record, while the report of Mr. Climie, for Granada, substantially confirmed by that of the sugar company, gives 93.62 inches for that year, being greater than any other year in either Granada or Masaya records. It may therefore be taken as the year of maximum rainfall within the range of the records. It is fortunate that this is the case, for we then have direct comparison by the same observer of the rainfall for 1897 with that for the three years covered by the observations of the fluctuations of Lake Nicaragua by this commission. The year of minimum rainfall occurs in the Masaya record for 1890, being only 20.52 inches, and being but little more than half of that for 1896, which is the next driest year in the Masaya record. The year is also the year of smallest precipitation in Dr. Flint's record at Rivas, and gives very much less rainfall than he gives for any other year covered by the Masaya record. It seems safe to conclude, therefore, that 1890 was actually the year of smallest precipitation within the records.

The Rivas record is the longest and most continuous, and is nearly on the canal line and nearly on the lake shore. In all these respects it promises very desirable and valuable information, completely covering the period from 1880 to date. An examination of this record, however, is somewhat disappointing. During the year 1898 Mr. J. A. Bull, an observer of the Nicaragua Canal Commission, was stationed at Las Lajas, near the point where the canal line leaves the shore of the lake. This point is only about 5 miles from Rivas, not greatly different in elevation or surrounding conditions that might affect the rainfall, and yet the precipitation recorded at Rivas exceeded that observed at Las Lajas by the percentages shown in the following table:

Rainfall at Las Lajas and Rivas, in inches.

Month.	Las Lajas.	Rivas.	Excess, per cent.
May	10.60	16.17	52.5
June	13.50	18.95	40.4
July	10.64	13.65	28.3
August	8.44	11.85	40.4
September	6.79	13.99	106.03
October	16.19	20.83	28.7
November	4.41	8.19	85.7
December	2.26	3.14	38.9
Total	72.83	106.77	46.6

This table indicates that the Rivas record is too large. Comparing it year by year with the recent records at Granada and Masaya also tends to confirm the result indicated above:

Rainfall, in inches, at Granada, Masaya, and Rivas.

Year.	Granada.	Masaya.	Rivas.	Excess, per cent.
1890	....	20.50	31.81	50.3
1891	....	49.98	66.03	32.1
1892	....	64.54	78.27	21.3
1893	....	72.86	106.13	45.7
1894	....	42.88	47.32	10.3
1895	....	41.26	47.68	15.56
1896	....	39.64	47.80	20.6
1897	93.62	....	123.43	31.8
1898	55.59	....	108.06	94.4
1899	56.93	....	67.82	19.10
1900	71.80	....	94.68	31.8

While Granada and Masaya are at considerable distance from Rivas and under somewhat different topographic conditions, there is no obvious reason why they should have less rainfall, and this evidence, so far as it goes, tends to confirm the indication of the Las Lajas record that the record at Rivas is too large. A similar result is obtained by a comparison of the Rivas record with the movements of Lake Nicaragua. Many months occur in which the rise of the lake, if all water had been held by a dam on the Rio San Juan and evaporation eliminated, would have been much less than the reported rainfall at Rivas, proving that the rainfall on the surface of Lake Nicaragua is less than recorded at Rivas.

These facts, coupled with the great importance of the accuracy of any record on which estimates are to depend, led to the establishment in June, 1900, of a rainfall observer in Rivas, whose gage is located not more than 300 yards from that upon which the long record has been taken. The observer employed by the commission was Mr. Charles Hayman, who thoroughly understood the work and who was cautioned to be extremely careful. The comparison of the observations is given on page 585. It shows that the record of Dr. Flint exceeded that taken by Mr. Hayman in every month, and seems to establish the fact that the results reported by Dr. Flint are too large.

Comparison of rainfall observations made at Rivas, Nicaragua, in 1900, by Dr. Earl Flint and the observer of the Isthmian Canal Commission.

[In inches.]

Day.	June.		July.		August.		September.		October.		November.	
	Dr. Flint.	Commission.	Dr. Flint.	Commission.	Dr. Flint.	Commission.	Dr. Flint.	Commission.	Dr. Flint.	Commission.	Dr. Flint.	Commission.
1	......	......	0.99	0.79	0.18	0.04	0.75	0.01	0.17	0.10	0.00	0.00
2	......	......	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.98	0.00	0.03
3	......	......	0.20	1.01	0.60	0.47	0.00	0.00	1.50	1.26	0.05	0.09
4	......	......	1.55	0.15	0.40	0.24	0.71	0.52	1.30	1.20	0.00	0.00
5	......	......	0.85	0.38	0.14	0.35	0.14	0.21	0.92	0.27	0.00	0.00
6	......	......	0.55	0.35	0.46	0.10	0.00	0.03	1.29	1.43	0.00	0.00
7	......	......	0.20	0.15	0.07	0.02	2.70	2.53	2.00	0.98	0.06	0.00
8	......	......	0.26	0.35	0.00	Tr.	0.63	0.37	0.13	0.07	0.08	0.05
9	......	......	0.66	0.36	0.48	0.35	0.16	Tr.	0.00	0.00	0.08	0.06
10	......	......	0.21	0.28	0.00	0.02	0.40	0.17	0.00	0.02	0.00	0.00
11	......	......	0.87	0.45	0.02	0.20	0.09	0.00	0.00	0.01	0.00	0.02
12	......	......	0.30	1.07	0.30	Tr.	0.74	0.69	0.50	0.39	0.02	0.00
13	......	......	1.49	0.04	0.00	0.00	0.20	0.03	0.11	0.11	0.08	0.00
14	......	......	0.07	0.06	1.60	1.10	0.06	0.00	0.33	0.11	0.00	0.00
15	0.00	0.01	0.00	0.17	0.13	0.02	0.00	0.98	0.02	0.04	0.00	0.04
16	0.70	0.04	0.40	0.16	0.03	0.01	1.70	0.44	0.31	0.17	0.30	0.39
17	0.60	0.99	0.20	0.16	0.00	Tr.	0.40	0.13	0.80	0.60	0.28	0.00
18	0.60	0.01	0.80	0.44	0.00	0.00	0.07	0.00	0.30	0.44	0.04	0.01
19	0.00	0.00	0.30	0.10	0.00	0.15	1.97	1.95	0.79	0.33	0.00	0.01
20	1.26	0.92	0.05	0.01	0.10	0.20	0.50	0.00	0.01	1.95	0.08	0.04
21	1.50	1.18	0.00	0.02	0.49	0.02	0.00	0.00	3.15	3.50	0.00	0.00
22	0.00	0.18	0.10	0.00	1.61	0.34	1.70	1.42	4.80	2.71	0.00	0.09
23	0.30	Tr.	0.07	0.00	0.50	1.35	1.42	1.07	0.31	0.19	0.00	0.00
24	1.48	1.19	0.04	0.10	0.90	0.59	0.57	0.37	0.90	0.65	0.00	0.00
25	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.99	0.61	0.01	0.00
26	0.00	0.00	0.00	0.00	0.43	0.70	0.08	0.05	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.70	0.13	0.00	0.00	0.00	0.00	0.11	0.06
28	0.07	0.03	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.37	0.02	0.00	0.00	4.18	3.40	0.00	0.00	0.00	0.00
30	0.75	0.51	0.08	0.06	0.00	0.00	3.41	2.48	0.00	0.00	0.00	0.07
31	......	......	0.00	0.07	0.00	0.43	......	......	0.00	0.00	......	......
	7.26	5.07	10.61	6.93	9.16	6.84	22.58	16.86	21.93	18.12	1.19	0.87
Excess	43 per cent.		53 per cent.		34 per cent.		34 per cent.		21 per cent.		37 per cent.	

These comparisons show that the record of Dr. Flint exceeded that taken for the Commission in every month, the average excess being about 37 per cent, confirming the indications previously referred to.

For these reasons it is deemed safer at present to eliminate the Rivas records from consideration in estimating the probable relation between the recorded rainfall and the action of Lake Nicaragua. We have then left available for comparison only those records for Masaya and Granada. Some of these are published in the report of the Nicaragua Canal Commission, pages 280 and 281, and comprise a complete record at Granada for 1877, taken by Dr. Flint, and complete records for 1883–84, observed by the National Institute at Granada. From the end of 1884 to the beginning of 1897 we have no records for

Granada, but for 1887 to 1896, inclusive, we have a complete record for the town of Masaya, taken by Mr. William Climie. This record is believed to be entirely reliable, but is not coincident with any observations of Lake Nicaragua. Early in 1897 Mr. Climie removed his gage to Granada, and gives the record for 1897 and 1898 at that place. The rainfall was also observed in 1897 by the officials of the Nicaragua Sugar Estates in the city of Granada, and their record continues up to the present time. It gives about 2 per cent less rainfall for 1897 than that of Mr. Climie, but the results are sufficiently accordant to confirm the substantial accuracy of both. During 1899 and 1900 a gage was maintained by this Commission at Granada, and these observations also serve to confirm the substantial accuracy of those furnished by the sugar company. We therefore have a continuous record from 1887 to date, the worst feature of which is that during the first ten years it was taken at Masaya and the last four years at Granada. Masaya is at an elevation of nearly 600 feet above Granada and is not on the drainage of Lake Nicaragua, but lies in a small basin which drains into Lake Masaya. Observations taken under the direction of Mr. Jacob Wiest in Masaya are at hand, covering the period from June 11, 1898, to November 30, 1899, which includes the major portion of three rainy seasons coincident with observations taken in Granada. The distance from Masaya to Granada is about 10 miles, which precludes comparison day by day, but a monthly comparison is given below, which shows considerable difference from the precipitation observed at Granada, that at Masaya being less.

Comparison of Granada and Masaya rainfall records, 1899 and 1900.

[In inches.]

Month.	1899.			Month.	1900.		
	Granada.	Masaya.	Differences.		Granada.	Masaya.	Differences.
Jan. 25-31	0.00	0.50	0.50	January	0.26	0.00	0.26
February	0.52	0.48	0.04	February	0.00	0.00	0.00
March	0.11	0.07	0.04	March	0.03	0.00	0.03
April	0.02	0.00	0.02	April	0.02	0.00	0.02
May	2.43	2.02	0.41	May	12.06	8.66	3.40
June	8.78	8.62	0.16	June	17.63	15.52	2.11
July	6.64	4.19	2.45	July	12.40	10.27	2.13
August	15.44	9.47	5.97	August	3.93	4.70	0.77
September	2.39	2.80	0.41	September	7.60	7.23	0.37
October	14.79	10.35	4.44	October	16.70	11.24	5.46
November	5.24	5.54	0.30	November	1.42	1.91	0.49
December	0.57	1.20	0.63	December	0.05	(a)	(a)
Total	56.93	45.24	11.69	Total	72.10	59.53	12.57

a No record.

MAXIMUM SUPPLY TO LAKE NICARAGUA.

To obtain the probable inflow to the lake during the season of greatest rainfall, 1897, we compare the rainfall at Granada for that year with the rainfall at the same place for some year during which the behavior of Lake Nicaragua was observed. For the purpose of this comparison the diagram (fig. 231) has been prepared. It shows three lines, each of which represents the relation of Granada rainfall to the run-off from the basin for one rainy season, the lines being plotted with the Granada rainfall as ordinates and the fluctuation of Lake Nicaragua that would have occurred if there had been neither outflow nor evaporation as abscissæ. This diagram is essentially accurate, involving no errors excepting those of observation. Appar-

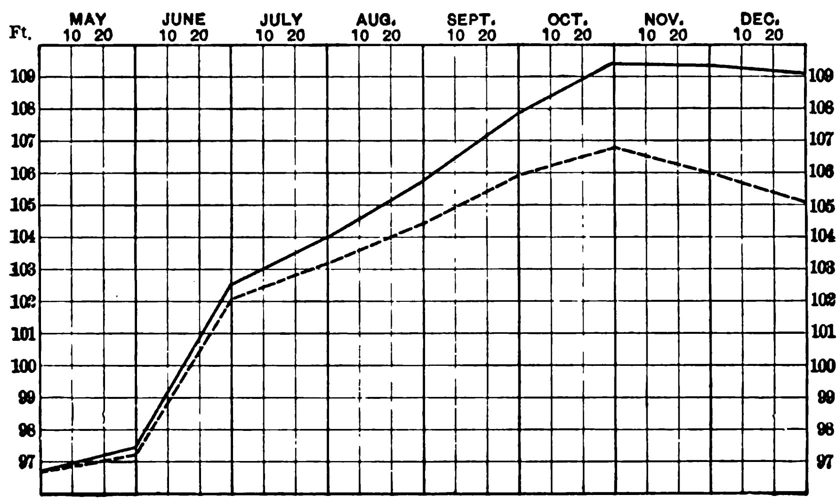


FIG. 230.—Estimated inflow into Lake Nicaraugua during 1897.

ently the two years of observation most suitable for comparing with 1897 are the years of 1898 and 1900, these being the years of greatest rainfall of the three observed. A diagram was plotted in which the line for 1898 was used as the basis for estimating the run-off corresponding to rainfalls observed in 1897. On this basis the fluctuation of the lake in 1897 would, if all water had been held, have amounted to nearly 14 feet, bringing the elevation of the lake in the spring of 1897 below 92 feet. There is abundant evidence that this stage of lake did not occur, and that the indication of the observations of 1898 is therefore erroneous, giving a much greater fluctuation than really occurred. This could be the case only if the rainfall for 1898 was lower in proportion to the run-off of the basin than that of 1897. That this was really the case is indicated by an examination of the annual total rainfall for Granada and Rivas on page 584. These show that whereas the record for Granada exceeded that for Rivas by 32 per cent in 1897, 19

per cent in 1899, and 31 per cent in 1900, in 1898 the excess was 94.4 per cent. Though the rainfall record of Rivas is rejected as inaccurate, the above indication is significant when taken in connection with the known facts of the fluctuation of Lake Nicaragua.

The estimate of run-off for 1897 was next made, the observations of 1900 being used as the basis. The results were obtained by months, by taking the run-off indicated by the given rainfall from the 1900 line on the diagram forming fig. 231 and adding thereto the evaporation corresponding to the period covered. The result is taken as the fluctuation of the lake due to the rainfall, and considered with evaporation in full play and with a dam in the river preventing outflow. This result is shown by the continuous line in fig. 230. The dotted

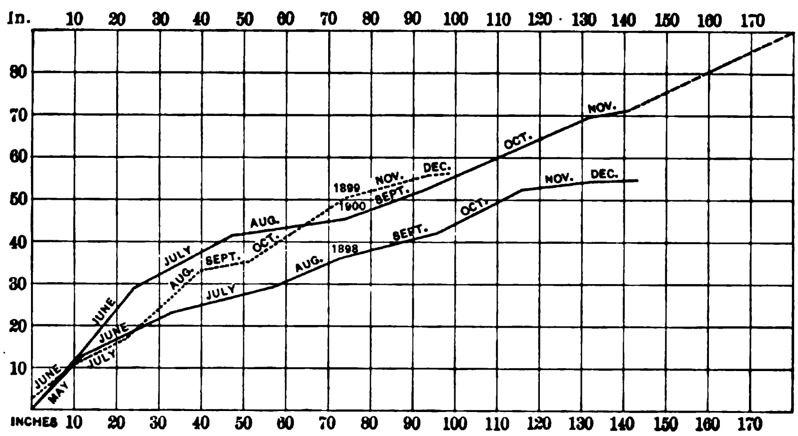


FIG. 231.—Run-off compared with Granada rainfall.

line in the same diagram shows the fluctuation of the lake on the assumption that the outflow to the San Juan River was that occurring in the state of nature due to the altitude of the lake. It therefore represents the actual changes that took place in the lake surface during 1897, as inferred from the observations of 1900.

The rainfall in 1897 was greater than that for 1900, and it was necessary to extrapolate the line indicated in fig. 231 for 1900. This is shown by the discontinuous line for 1900 on that figure.

The fluctuation of the lake as indicated by this method is about 10 feet in the aggregate, or a little over 8 feet net. The stage of January 4 having been observed by the Nicaragua Canal Commission, it is known that the lake stood at about 105 at the end of December, 1897. The elevation indicated for May, 1897, 96.7, is somewhat lower than that indicated by the estimates made on page 581, and by reports of people who were in Nicaragua at that time, notably Mr. William Climie. But if this is the case the errors are on the side of safety, and the indications of the diagram may safely be taken as correct.

THE SEASON OF MINIMUM SUPPLY.

To obtain the probable fluctuation of the lake during the period of nineteen months ending May, 1901, which, as has been shown, includes two dry seasons, and the driest rainy season in all the records at hand, comparison is made between the rainfall for that period at Masaya and the rainfall for 1900 at the same place when the behavior of the lake was observed. The only two years available for this comparison are 1899 and 1900, the former being not quite complete. The relation of rainfall at Masaya to the fluctuation of the lake is shown in fig. 232, two lines being plotted, for 1899 and 1900, respectively, as indicated, on the same basis as fig. 231, already described.

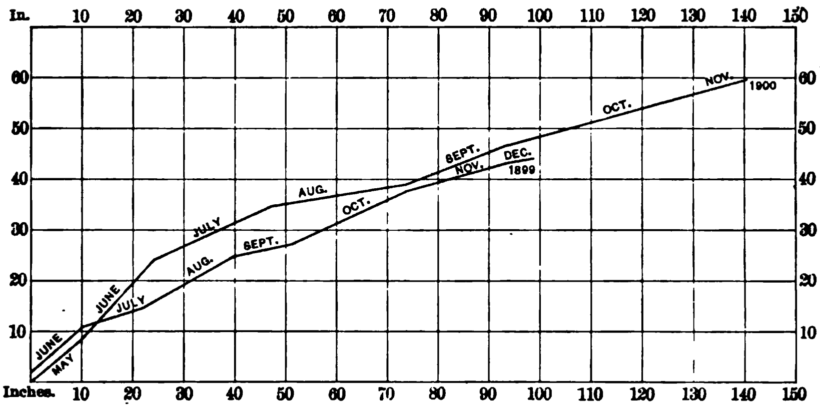


FIG. 232.—Run-off compared with Masaya rainfall.

It will be seen from the diagram that by taking 1900 as the basis of comparison we obtain more conservative results than if 1899 were used; that is, a given rainfall at Masaya corresponds to less inflow to the lake than in 1899, this difference being for a dry season on the side of safety.

On both diagrams it will be noticed that in the latter part of the year the line tends to approach a horizontal position, there being a considerable run-off during the months of November and December with little or no rainfall, this, of course, being due to the rainfall of previous months. During 1890 there were only 20.52 inches of rainfall at Masaya, and this quantity corresponds to the rainfall plotted in the diagram before the end of June, at a time when the rainy season had only endured a little over a month and when considerable rain had fallen that had not yet reached the lake, but which did so later on. This introduces an actual error into the assumption which may be important, but the magnitude of which can not be accurately estimated. Against this error must be placed the well-known fact that for a large

rainfall the percentage of run-off is greater than for a small one on an average, or, in other words, the percentage of run-off to rainfall in 1900 was in the aggregate greater than in 1890. How far these two errors balance each other can not, of course, be known, but it is practically certain that their resultant is to an important degree an error on the side of safety.

The result is shown in fig. 233, and indicates the fall of the lake from the 1st of November, 1889, to the end of May, 1891, the driest consecutive period of nineteen months of which we have record. It indicates that if all water had been held by a dam at the outlet of the lake, and 1,000 cubic feet per second had been used for canal purposes throughout that period, the surface of the lake would have declined 6.2 feet. No resistance can be offered to the decline of the lake during a dry period except to keep all sluices closed, and therefore we may expect an unavoidable decline under extreme conditions of 6.2 feet in nineteen months.

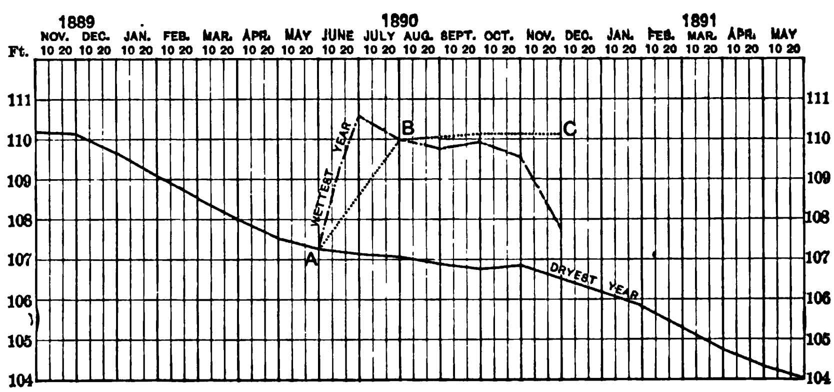


FIG. 233.—Fluctuation of Lake Nicaragua during driest and wettest seasons.

The rise of the lake in seasons of excessive rainfall can be resisted by the discharge of water through the dam at Boca San Carlos and into the valley of Grande River on the west side.

It is not permissible to use the latter outlet extensively, owing to the danger of carrying to the sea an excessive quantity of detritus, and thereby obstructing the harbor at Brito. It is necessary, therefore, that the surplus waters be discharged to the eastward through the San Juan River.

If adjustable sluices be provided at Boca San Carlos, to discharge any desired quantity of water, the problem resolves itself into the estimation of the capacity of the canalized San Juan River. This is a function of the cross section, roughness, and slope, the latter depending upon the stage of the lake.

To determine the coefficient of roughness, computations were made of the value of the factor "n" in Kutter's formula, using measured

slope, velocity, cross section, and discharge of the San Juan River. These computations, which were exceedingly laborious, were made by Mr. S. H. Woodard, and the resulting mean values of "n" varied from .022 to .024. Applying the latter value to the canalized river, its discharging capacity was computed for the various elevations at the lake and at Boca San Carlos. The accompanying diagram (fig. 234) has been constructed by Mr. Woodard, showing his results. It shows that with water at the dam held at 104 the discharging capacity varies from zero to 63,000 cubic feet per second, while the lake level rises from 104 to 110.

Applying these facts to the lake supply, shown in figs. 231 and 232, we obtain results shown in fig. 233.

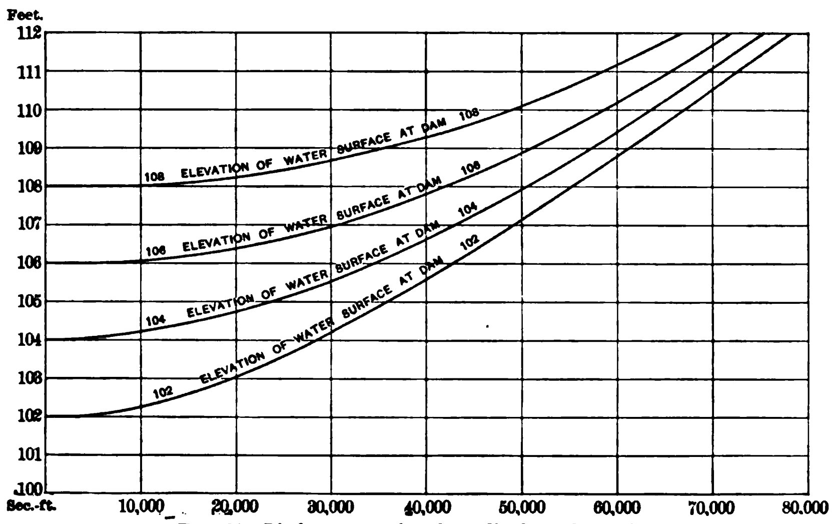


FIG. 234.—Discharge capacity of canalized San Juan River.

That is, if the canal had been constructed and the lake surface was at 107.3 on the 1st of June, 1897, the lake would have risen to 110.6 by the end of June in spite of the discharge through the river with sluices left open, holding the water level at 104 at the dam. During July and August the discharge would have been greater than the inflow, and the lake might have been drawn down to 109.8. It would have risen slightly in September and receded again in October. But after June the discharge would have been checked, because it is necessary to hold the lake at 110.2 at the end of October to provide against exceptional drought. The aim would have been, therefore, to hold the lake as nearly as possible to the line A B C, and after the end of June this could have been accomplished.

If, instead of the very wet year 1897, the driest year in the record, 1890, had occurred, the sluices would have remained closed, and the lake surface would have declined 3.3 feet under the combined influence

of inflow, evaporation, and the consumption of 1,000 cubic feet per second, from 107.3 to 104, by the opening of the following rainy season, when the lake may be expected to rise.

If the elevation of 104 feet be adopted as the minimum summit level to be permitted, the lake must be at a stage not lower than 107.3 feet at the beginning of the rainy season, as it may be a season of minimum precipitation, so that the lake will decline 3.3 feet in the ensuing twelve months. To do this, each rainy season must be closed with the lake at 110.2, as the unavoidable loss during the dry season is 2.9 feet, as shown by fig. 233. Should the following wet season be one of heavy rainfall, like 1897, the lake will rise to about 110.6 in spite of all the discharge of which the river is capable. If, instead of a very wet season, the rainfall should be slight, like that of 1890, the lake would decline to 104 by the opening of the next rainy season, with all the sluices closed.

Our present information indicates, therefore, that the lake can be kept within limits of 6.6 feet, provided two minimum years do not occur in succession, which seems to be a safe assumption.

As neither the maximum nor minimum years have been actually observed, there is necessarily some uncertainty in any estimates that can be made for such years. It has been the effort to make the estimates conservative, as indicated in the discussion. If actual conditions should occur which are more extreme than those we have considered, it might be necessary to allow a greater fluctuation than 6.6 feet. If a season of greater inflow than that estimated for 1897 should occur, it would be necessary to allow the lake to stand temporarily at a higher level than 110.6. If experience should show a season of less inflow than that estimated for 1890, it would be necessary to begin each rainy season with the lake surface higher than 107.3 and to close it with the lake above 110.2 in order to prevent its decline below 104. A very slight increase in the upper limit allowed is a great relief to the conditions, since this not only increases the allowable fluctuations, but also increases the discharge capacity of the river. If the lake should reach a height of 111 feet it would only be repeating the conditions that have actually occurred in its natural state. The water might rise to a height of 112 feet, or even higher, without doing any great amount of damage, and it is probable that permission to allow this could, without difficulty, be included in the concession. We could then begin each month of June with the lake at elevation 108; if the rainy season should furnish 20 per cent more water than that estimated for 1897 we could still control the lake within the 112-foot limit. If, instead, the rainy season should furnish only one-half the supply estimated for 1890, the lake would fall to just 104 by the opening of the next rainy season. This is certainly a very wide margin of safety.

HYDROGRAPHY OF PANAMA ROUTE.

The hydrographic problem of the Panama canal project requires a knowledge of the magnitude and habit of the flood discharge of the Chagres River, and also in a minor degree of the tributaries of the Chagres and of the Grande River on the southern end of the line. It also requires a knowledge of the minimum flow of the Chagres River considered as a feeder to the summit level and the locks of the canal. Incidental to these matters the determination of rainfall is important, considered both as a source of water supply and as a hindrance to construction. Some observations upon these points were taken by the old Panama Canal Company, and since the organization of the new company the records of the discharge of the Chagres at Gamboa and Bohio have been much more thorough and complete. Since April, 1899, measurements have also been made at Alhajuela, where it is proposed by the canal company to construct a reservoir to serve as a regulator of the floods of the river and to store water for the use of the canal.

The work undertaken by the Isthmian Canal Commission consists mainly in an examination of the observations and results already obtained by the company, of a verification of their methods by actual field observations, and of an extension of the rainfall information, as far as possible, over the basin of the Chagres River.

These latter operations were undertaken in November, 1899, and placed in charge of Mr. W. W. Schlecht. In July and August, 1900, the writer made a personal inspection of the records of the old and new companies at the office of the Panama Canal Company, in Paris, obtaining many details of value regarding the methods and data employed in arriving at the conclusion published by the company. It was found that the data obtained by the old company prior to the organization of the new were very fragmentary and incomplete, considerable periods being entirely skipped. The most serious lack of information was with respect to the magnitude of the great floods that have been observed upon the isthmus, especially the maximum flood in 1879. The observations taken by the new company are far more complete and satisfactory, but, unfortunately, they do not include any flood discharge as great as those that occurred under the régime of the old company.

At present all stream measurements by the Panama Canal Company are confined to the Chagres River, which really presents the only important hydrographic problems relative to an interoceanic canal on the Isthmus of Panama. In order to obtain the daily mean gage height, and a record of the rapid fluctuations of the river, the canal company has installed continuous self-registering river gages or "fluviographs," with an observer at each. The scale of the fluvio-

graph record is 1 millimeter (vertical) = 2 centimeters of rise, and 5 millimeters (horizontal) = 1 hour, so that each centimeter of rise and each ten minutes of time may be easily read. These readings were checked each day at 6 a. m. and 6 p. m., and, with very few exceptions, no material errors were found.

The measurements for the discharge are made by the company by means of floats of 1 to 3 feet immersion and 2 to 3 inches diameter, the latter size being used only at times of flood, so all may be considered as surface floats, and a length of course of 60 meters at Alhajuela and Gamboa and 80 meters at Bohio. Cross sections of the courses are taken 10 meters apart, and from these a table of mean sectional areas for different stages of the river is computed for each station. Following are the instructions to the observers concerning the method of obtaining the discharge, which are carefully followed:

The observations should be made in calm weather. The floats should have but a small portion exposed above the surface of the water. The float should be liberated a short distance above the first profile, so that at the moment it crosses that section it will have attained the velocity of the water. The observer will note the moment of passage at the first section, and then go to the lower section and note its passage at that section.

The discharge is then obtained by means of the formula—

$D = 0.80\ A\ V.$

D = discharge; A = mean sectional area; V = the mean velocity of the floats.

CHAGRES RIVER.

The main trunk of the Chagres is formed by two principal branches. The Pequeni rises near the Caribbean coast and flows nearly south until it meets the Chagres proper, a short distance above Alhajuela. The general course of the Upper Chagres from its source is southwest, and it continues in the same general direction after receiving the waters of the Pequeni to the mouth of the Obispo, where the proposed canal line leaves its valley. Its course is then westward to Tavernilla, and from that point to its mouth its course is nearly northwesterly. Its total length is over 120 miles, without including minor bends, although the width of the isthmus at its mouth is less than 50 miles.

The district below Bohio drained by the Chagres and its tributaries consists mainly of low hills and swamps. The river is sluggish, the effect of the tide being plainly perceptible at Bohio at low water, although the tidal fluctuations of the Caribbean are very slight. Above this point there is some modification, the declivity being greater and the country higher and less swampy. Several rapids occur in this portion of the river, and above Obispo rapids are frequent and the river is swift. The Upper Chagres is flanked by steep, rocky hills, clothed with luxuriant vegetation; rapids are frequent; and the water is

everywhere swift and is very clear except in times of freshet. The stream is sinuous in many parts and is frequently bordered by rock cliffs, lending variety to the scene, which is everywhere one of surpassing beauty. In some cases the convex curve of the stream with its swift current has undermined the limestone cliffs, leaving overhanging ledges and producing caverns of considerable extent.

The drainage area of the Chagres River above Bohio is only approximately known, and depends upon the following data:

Totten's "Map of the Isthmus of Panama" gives that portion of the divide lying between latitude 9° 0′ and 9° 20′ north and longitude 80° 30′ and 80° 50′ west. It also gives the divide of the Boqueron River—i. e., the northwestern extremity of the drainage area. The survey of the Mandinga River by this Commission gives the eastern divide at longitude 79° 15′ west.

The survey of the Chagres River above Santa Barbara gives the northeastern extremity of the drainage basin at latitude 9° 25′ north, longitude 79° 15′ west. It also gives an idea of the size and general direction of the tributaries.

The northern and southern portions of the divide, not included in Totten's map, have been approximately determined from the Atlantic and Pacific oceans, and in these parts the greatest probable error exists.

The various drainage areas are about as follows:

Drainage areas in watershed of Chagres River.

	Square miles.
Total area of Chagres drainage basin	1,400
Upper Chagres (above Pequeni)	300
Rio Pequeni	175
Above Alhajuela	505
Between Alhajuela and Gamboa	130
Above Gamboa	635
Rio Obispo	38
Between Gamboa and Bohio	245
Above Bohio	880
Between Alhajuela and Bohio	375
Below Bohio	520
Lower Gatun	145

ALHAJUELA STATION, ON CHAGRES RIVER.

This is the point on the Chagres, about 11 miles above Gamboa, where the Panama Canal Company proposes to build a high masonry dam to impound water for the use of the canal and to assist in the storage of floods. The dam site is about 7 miles by the bends of the river below "Dos Bocas," the junction of the two main branches of the Chagres, the gaging station being about half a mile below the dam site. The river here has high, steep banks on each side, a width of about 250 feet, and at normal stage a mean depth of 4 or 5 feet; it

is on a slight bend, and the cross sections along the course differ considerably in area and conformation. About 60 feet above the upper range a three-fourths-inch cable is stretched across the river with marks giving at normal stage the one-fourth, one-half, and three-fourths points of the width of the river; these marks are used to show the points at which to release the floats. The fluviograph is 200 yards below, and a secondary rod divided into centimeters is firmly set in the bank at the gaging station. The reading of this rod is used as the argument in the table giving the mean area.

On October 31, 1899, a No. 8 telegraph wire was stretched across the river, about 60 feet above the canal company's cable. This was divided into 10-foot lengths and was used to hold the boat in a fixed position while the velocity was being measured. The wire could be readily lowered while in use so that a man in the bow could seize it and hold the boat in the desired position, and when not in use it was raised 20 or 25 feet above the surface of the river, beyond the reach of floods.

The first current-meter measurement was made on October 31, 1899, with new "Small Price Electric Meter No. 35." Two simultaneous determinations of the discharge were made, the first by measuring the velocity at 0.6 foot depth below the surface at each station, and the second by measuring the velocity at each foot of depth at the same stations and then taking the mean as the mean velocity at that station. The river was divided into twelve sections, varying from 10 feet wide near the banks, where the velocity across the stream changes rapidly, to 30 feet near the center, where it is more uniform.

Following are the results:

Fluviograph = 28.565 meters.
1st method. Mean velocity = 1.92 feet per second.
Discharge = 2,280 second-feet.
2d method. Mean velocity = 1.90 feet per second.
Discharge = 2,257 second-feet.

From the above we see that at Alhajuela the velocity at 0.6 foot depth below the surface gives the mean velocity of the section, with an error of about 1 per cent.

Gagings made by this method gave results almost uniformly 20 per cent greater than those obtained by the company, thus justifying General Abbot's criticism of their method of using the coefficient 0.8, this factor being too small. Another error of 3 to 5 per cent is introduced by taking as the mean velocity the quotient of the length of the course by the mean time of the floats. The proper method is to compute the velocity of each float separately and apply it only to its own section.

Seventy-four measurements were made for the Commission at Alhajuela, and monthly estimates of discharge were computed for 1900. The

A. BORING PARTY AT PANAMA.

B. ALHAJUELA DAM SITE, SHOWING ROCK AT WATER'S EDGE.

results obtained by the company since the station was established, in April, 1899, as well as those obtained by the Commission, are given below.

Estimated monthly discharge of Chagres River at Alhajuela, from observations of the Panama Canal Company.

[Drainage area, 505 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall in basin, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1899.							
April 15 to 30	1,024	600	706	22,400	....	....	....
May	28,420	494	1,590	97,760	3.15	3.63	....
June	4,200	1,165	2,150	127,930	4.26	4.75	....
July	15,640	1,235	2,220	136,500	4.40	5.07	....
August	27,430	1,660	3,280	201,680	6.50	7.49	....
September	11,160	1,450	2,400	142,800	4.75	5.30	....
October	9,990	1,590	2,650	162,940	5.25	6.05	....
November	28,660	1,520	2,930	174,350	5.80	6.47	....
December	11,160	1,380	2,260	138,960	4.47	5.15	....
The year	28,660	....	2,430	1,205,320	....	43.91	....
1900.							
January	11,150	1,020	1,590	97,760	3.15	3.63	2.27
February	1,130	565	812	45,100	1.60	1.67	0.38
March	777	425	530	32,590	1.05	1.21	0.32
April	2,050	318	565	33,620	1.12	1.25	4.06
May	13,770	388	1,340	82,400	2.65	3.06	11.88
June	7,730	880	1,550	92,230	3.07	3.42	16.57
July	18,180	1,230	2,190	134,660	4.33	4.99	14.64
August	20,400	1,520	2,820	173,400	5.58	6.43	13.01
September	11,650	1,270	2,150	127,930	4.26	4.75	15.60
October	24,780	1,730	3,210	197,380	6.36	7.33	16.39
November	14,680	1,620	2,290	140,800	5.87	6.55	14.92
December	20,540	1,130	2,290	140,800	4.53	5.22	3.76
The year	24,780	318	1,840	1,334,300	3.64	49.51	113.80

Estimated monthly discharge of Chagres River at Alhajuela, from observations of the Isthmian Canal Commission.

[Drainage area, 505 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall in basin, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1900.							
January	14,535	1,230	1,941	119,350	3.84	4.43	2.27
February	1,365	652	916	50,870	1.81	1.88	0.38
March	849	497	608	37,380	1.20	1.38	0.32
April	2,032	395	631	37,550	1.25	1.39	4.06
May	17,460	476	1,588	97,640	3.14	3.62	11.88
June	10,395	1,025	1,934	115,080	3.83	4.27	16.57
July	21,950	1,814	3,148	193,560	6.23	7.18	14.64
August	27,400	2,157	4,094	251,730	8.11	9.35	13.01
September	17,065	1,720	3,101	184,520	6.14	6.85	15.60
October	31,740	2,710	4,889	300,610	9.68	11.16	16.39
November	20,670	2,223	4,504	268,010	8.92	9.95	14.92
December	28,020	1,396	3,286	202,050	6.50	7.49	3.76
The year	31,740	395	2,567	1,858,350	....	68.95	113.80

Ratio of run-off to rainfall = 60 per cent.

The following experiments with rod floats were made at Alhajuela, by Mr. W. W. Schlecht, to find the relation between the surface velocities and the mean velocity in a vertical section.

Float experiments made August 22, 1900.—Fluviograph=28.81.

I. FULL-DEPTH ROD FLOATS OF 2 TO 3 INCHES UNIFORM DIAMETER.

Distance from right bank (feet)	20	40	60	80	100	120	140	160	180	200	220
Length of floats (feet)	7.5	5.0	5.0	5.0	3.5	3.5	3.5	3.5	3.5	3.5	2.0
Elapsed time (seconds)	87	78	78	77	75	57	55	55	59	64	93
Velocity (feet per second)	2.27	2.53	2.53	2.56	2.63	3.46	3.58	3.58	3.34	3.08	2.12

Mean=2.88 feet per second.

II. FLOATS OF 1½ FEET LENGTH, 2 INCHES UNIFORM DIAMETER.

Distance from right bank (feet)	20	40	60	80	100	120	140	160	180	200	220
Elapsed time (seconds)	72	75	70	68	63	53	50	45	51	58	71
Velocity (feet per second)	2.74	2.63	2.81	2.90	3.13	3.72	3.94	4.38	3.86	3.40	2.77

Mean=3.30 feet per second.
Ratio=2.88+3.30=0.87.

A. CHAGRES RIVER BELOW ALHAJUELA.

B. CHAGRES RIVER NEAR GORGONA.

The discharge obtained by using 2.88 as the mean velocity is 4,040 second-feet, which compares very favorably with discharges obtained by means of current meters.

SANTA BARBARA STATION ON CHAGRES RIVER.

The gage height of the Chagres River at Santa Barbara was read by C. Clauzel at 6 a. m. and 6 p. m. and at times of important fluctuations. The discharge measurements were made with current meters and surface floats. After comparing several float measurements with simultaneous current meter measurements a coefficient of 0.85 was adopted to reduce the observed velocity of the floats to the mean velocity of the cross section. Thirty-five current-meter and 110 float measurements were made, from which a rating table was constructed, and the following table of discharges was computed:

Estimated monthly discharge of Chagres River at Santa Barbara

[Drainage area, 300 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall in basin, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1900.							
January	8,360	700	1,205	74,090	4.02	4.63	1.34
February	1,020	390	542	30,100	1.81	1.88	0.21
March	415	320	369	22,690	1.23	1.41	0.10
April	8,570	300	430	25,590	1.43	1.60	5.52
May	16,625	310	1,003	61,670	3.34	3.88	13.15
June	6,510	610	1,338	79,620	4.46	4.98	21.51
July	19,875	802	1,900	116,830	6.33	7.31	13.53
August	18,250	1,020	2,348	144,370	7.83	9.02	11.22
September	13,055	965	1,717	102,170	5.72	6.38	16.08
October	33,600	1,365	3,601	221,420	12.00	13.84	17.00

TRIBUTARIES BETWEEN ALHAJUELA AND GAMBOA.

The mean monthly discharge of all the tributaries between Alhajuela and Gamboa was obtained by subtracting the discharge at the former station from the discharge at the latter, month by month.

Estimated monthly discharge of tributaries to the Chagres River between Alhajuela and Gamboa.

[Drainage area, 130 square miles.]

Month.	Mean discharge in second-feet.	Total in acre-feet.	Run-off.		Rainfall, inches.[a]
			Second-feet per square mile.	Depth in inches.	
1900.					
January	85	5,226	0.65	0.75	1.41
February	54	2,999	0.42	0.44	0.10
March	33	2,029	0.25	0.29	0.08
April	6	357	0.05	0.06	3.66
May	27	1,660	0.21	0.24	8.46
June	492	29,276	3.78	4.20	14.97
July	956	58,782	7.35	8.46	16.58
August	598	36,769	4.60	5.30	9.74
September	649	38,620	4.99	5.74	13.22
October	957	58,840	7.36	8.47	12.68
November	911	54,210	7.01	7.82	12.01
December	94	5,780	0.72	0.83	0.97
The year	407	294,548	....	42.60	93.88

Ratio of run-off to rainfall = 45 per cent.

[a] Mean of observations Alhajuela and Gamboa.

The chief tributaries between Alhajuela and Gamboa are the Chilibre and the Gatuncillo. Weekly gagings of these were made and their gage height was read three times a week. These observations in a general way furnished the relation of the discharge of each one to the total increase of discharge between the stations, which is as follows:

	Per cent.
Chilibre	36
Gatuncillo	26
Other sources	38
Total	100

The highest observed gage height on the Chilibre was 22 feet, giving a computed discharge of 3,700 second-feet. On the Gatuncillo the highest observed gage height was 16 feet, giving a computed discharge of 2,500 second-feet.

GAMBOA STATION ON CHAGRES RIVER.

This is the station of longest record of any on the Isthmus. It is near the point where the canal line leaves the valley of the Chagres, the river valley ascending from this point to the northeast, while the

SITE OF OBISPO LOCKS, PANAMA.

Used as rating station for current meters by Isthmian Canal Commission.

canal line proceeds to the southeast to cut through the continental divide to the Pacific. It was at one time proposed to construct a dam at this point, and the old canal company began observations here, but a careful examination of the records by the writer, in Paris, failed to bring to light any continuous record of river stages prior to 1892, although a number of discharge measurements for 1889–1891 were obtained.

The canal company's gaging station at Gamboa is about 100 yards above the mouth of the Obispo River, or about 300 yards below the proposed dam site. Although by no means an ideal station on account of the tributary just below it, which may at times produce backwater, and also on account of the broken water produced by a whirlpool above it, still it is the best section within several miles on each side of it. The banks are fairly high and the course is straight. Floods rising over gage height 18 meters will cover the left bank, and some water will flow through the channel dug for the canal, and thus will not be included in the discharge measured at the gaging station. It then becomes necessary to make the measurement at Gorgona, where, although the discharge of the Obispo is added, better results are obtained. The fluviograph, which is similar to the one at Alhajuela, is one-half mile above the gaging station. Discharge measurements are made with floats in the same way as at Alhajuela.

Annual summary of discharge measurements made by the Panama Canal Company at Gamboa.

Year.	Maximum.	Minimum.	Mean.	Total in acre-feet.	Run-off. Second-feet per square mile.	Run-off. Depth in inches.	Rainfall at Colon.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*				
1892	42,000	....	....	....	....	....	....
1893	51,100	759	3,610	2,612,607	5.69	77.14	131.89
1894	26,190	530	3,770	2,732,284	5.94	80.68	153.69
1895	27,990	565	2,880	2,083,740	4.53	61.55	151.54
1896	....	....	2,880	2,093,910	4.53	61.83	131.51
1897	42,190	....	3,880	2,806,070	6.11	82.84	138.03
1898	28,770	777	3,000	2,169,630	4.72	64.05	115.55
1899	26,190	706	2,580	1,870,500	4.06	55.23	133.02
1900	23,720	388	2,360	1,705,100	3.72	50.35	[a]108.01

[a] Mean rainfall on basin.

Discharge measurements made on Chagres River at Gamboa in 1889.

September.			October.			November.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
27......	15.4	4,448	2......	15.7	5,154	2......	15.4	5,366
30......	15.4	4,977	5......	15.8	5,613	6......	15.2	4,236
			9......	15.1	3,954	9......	15.4	4,942
			12......	15.4	5,330	14......	15.0	3,812
			15......	15.0	3,459	16......	15.4	4,765
			19......	15.9	6,107	20......	15.2	4,660
			23......	15.4	4,977	22......	17.1	11,614
			26......	15.1	3,600	30......	15.1	3,600
			30......	15.2	4,165			
Mean ...	....		Mean ..	4,707		Mean ..	5,374	

Discharge measurements made on Chagres River at Gamboa in 1890.

January.			February.			March.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
13......	16.8	9,531	14......	14.5	1,412	1......	14.3	1,270
			21......	14.4	1,412	6......	14.2	1,094
			27......	14.3	1,236	11......	14.2	882
						19......	14.2	882
						27......	14.4	1,341
Mean ...	9,531		Mean ..	1,353		Mean ..	1,094	

April.			May.			June.		
Day	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
8......	14.2	812	3......	17.6	14,470	3......	15.4	4,463
10......	14.1	600	6......	14.8	3,530	6......	15.6	4,518
14......	14.1	600	9......	14.4	1,165	7......	16.8	10,307
17......	14.1	565	12......	15.8	6,707	10......	16.4	8,472
19......	14.1	600	16......	16.1	8,013	13......	14.8	2,471
22......	14.1	586	20......	15.2	3,990	17......	16.6	11,120
25......	14.1	777	23......	14.8	2,824	20......	15.5	4,730
29......	14.4	1,306	27......	15.2	3,990	24......	15.1	3,636
			30......	14.8	2,753	27......	15.2	3,777
Mean ...	731		Mean ..	5,271		Mean ..	5,946	

Discharge measurements made on Chagres River at Gamboa in 1890.

July.			August.			September.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
1	15.4	4,483	1	14.8	2,400	5	15.4	4,977
7	15.2	3,954	5	15.4	4,624	9	15.2	4,130
8	15.2	3,636	8	15.3	4,377	12	15.6	5,330
8	17.2	11,331	12	15.8	5,720	13	17.7	15,890
16	15.6	5,013	14	16.2	7,554	16	16.0	6,920
18	15.4	4,518	19	15.3	4,306	19	15.5	5,083
22	15.2	3,777	22	15.2	4,060	21	16.3	8,225
25	16.6	8,930	26	15.9	6,954	26	15.4	4,342
29	15.0	3,000	29	15.3	4,448	30	15.9	6,460
			31	17.1	12,320			
Mean	5,404		Mean	5,676		Mean	6,817	

October.			November.			December.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
3	15.4	4,518	4	15.2	3,777	2	18.0	14,296
7	15.4	4,660	7	15.1	3,565	5	15.6	5,471
10	15.9	5,825	11	15.4	4,412	9	15.6	6,178
14	15.3	3,742	14	15.2	3,990	12	15.2	3,600
17	15.2	4,024	18	15.0	3,018	16	15.4	4,554
21	15.1	3,600	22	15.6	5,048	19	15.5	5,295
24	17.1	10,307	25	15.4	4,589	23	15.4	4,836
25	18.4	17,900	29	15.1	3,248	26	15.4	5,013
31	15.3	3,777				30	15.2	3,990
Mean	6,483		Mean	3,956		Mean	5,915	

Discharge measurements made on Chagres River at Gamboa in 1891.

January.			February.			March.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
2	15.1	3,353	3	14.5	1,236	3	14.3	720
6	14.9	2,612	6	14.5	988	6	14.3	681
9	15.1	3,177	10	14.4	1,130	10	14.3	745
13	14.7	1,836	13	14.5	1,024	13	14.3	582
16	14.7	1,765	17	14.4	847	17	14.2	540
20	14.6	1,482	20	14.4	928	20	14.2	551
23	14.6	1,353	24	14.3	709	24	14.2	600
27	14.6	1,341	27	14.3	709	27	14.2	434
30	14.5	1,341				31	14.2	515
Mean		2,051	Mean		946	Mean		596

April.			May.			June.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
3	14.2	572	1	14.2	512	2	14.7	2,051
7	14.1	568	4	18.2	18,285	5	14.7	2,365
10	14.1	547	8	14.5	1,701	9	14.7	2,230
14	14.1	441	12	14.1	618	12	14.3	1,097
17	14.1	614	15	14.1	512	16	14.5	1,750
21	14.2	522	19	15.0	3,036	19	15.8	6,080
24	14.1	544	22	14.4	1,423	23	14.7	1,860
28	14.1	473	26	14.7	2,404	26	14.4	1,377
			29	14.8	2,580	30	14.8	2,602
Mean		535	Mean		4,524	Mean		2,379

Discharge measurements made on Chagres River at Gamboa in 1891—Continued.

July.			August.			September.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
3......	14.5	1,518	4......	14.9	2,683	1......	15.4	4,130
7......	14.6	1,871	7......	15.2	3,777	4......	15.1	3,000
8......	17.5	11,967	11......	14.9	2,577	8......	15.3	4,342
13......	16.0	5,825	14......	14.7	2,259	11......	14.8	2,259
17......	14.7	1,977	18......	15.0	3,142	15......	14.7	2,083
21......	15.0	3,000	21......	14.8	2,330	18......	14.7	1,518
24......	14.7	1,588	25......	15.0	3,354	21......	15.7	4,590
28......	15.5	4,483	28......	14.7	2,120	29......	14.8	2,330
31......	14.7	1,906						
Mean		3,793	Mean		2,780	Mean		3,032

October.			November.			December.		
Day.	Height.	Discharge.	Day.	Height.	Discharge.	Day.	Height.	Discharge.
	Meters.	*Sec.-ft.*		*Meters.*	*Sec.-ft.*		*Meters.*	*Sec.-ft.*
2......	14.9	2,316	3......	15.1	3,142	1......	16.9	9,955
6......	14.7	2,120	6......	15.5	4,377	4......	15.6	4,907
9......	14.6	1,870	10......	15.4	3,636	8......	17.5	12,885
13......	15.1	3,390	13......	15.2	3,565	11......	15.1	2,930
16......	16.4	6,848	17......	14.9	2,294	15......	15.0	2,790
20......	15.4	4,095	19......	19.2	26,475	18......	14.8	2,153
23......	15.6	4,836	24......	15.3	3,848	22......	14.8	3,083
27......	15.5	4,695	27......	17.5	12,637	27......	14.7	1,730
30......	15.4	3,954				29......	14.6	1,590
31......	17.0	10,555						
Mean		4,468	Mean		7,497	Mean		4,670

Estimated monthly discharge of Chagres River at Gamboa, from measurements by the Panama Canal Company.

[Drainage area, 635 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Colon rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1892.							
May	28,770	2,345	5,311	326,561	8.36	9.64	18.03
June	17,930	2,260	3,590	213,620	5.65	6.30	16.97
July	27,320	2,232	7,114	437,423	11.20	12.91	21.77
August	25,910	3,531	5,950	363,084	9.37	10.80	15.98
September	7,275	3,178	4,476	266,341	7.05	7.87	16.26
October	19,840	3,284	5,848	359,580	9.21	10.62	6.69
November	42,000	3,990	6,715	399,570	10.57	11.80	26.30
December	25,200	2,860	5,968	366,958	9.40	10.84	11.30
The year	42,000	....	....	2,733,137	....	....	....
1893.							
January	2,892	1,865	2,293	140,991	3.61	4.16	1.73
February	3,563	1,423	1,993	110,686	3.13	3.26	3.82
March	6,512	759	1,134	69,727	1.79	2.06	1.81
April	23,102	1,201	3,190	189,818	5.02	5.60	8.07
May	26,620	1,497	3,045	187,229	4.80	5.53	6.56
June	6,039	2,147	3,200	190,410	5.04	5.62	12.32
July	17,300	2,034	3,472	213,484	5.47	6.31	11.50
August	21,140	3,146	4,538	279,031	7.15	8.24	15.12
September	10,389	2,430	3,813	226,890	6.00	6.69	9.92
October	9,535	2,260	3,733	229,533	5.88	6.78	12.28
November	19,840	3,249	4,494	267,412	7.08	7.90	17.80
December	51,100	3,178	8,252	507,396	13.00	14.99	30.94
The year	51,100	759	3,610	2,612,607	5.69	77.14	131.89
1894.							
January	26,189	2,175	3,858	237,219	6.08	7.01	5.35
February	2,260	1,201	1,633	90,692	2.57	2.68	1.65
March	1,225	742	948	58,290	1.50	1.73	0.35
April	2,317	572	760	45,223	1.20	1.34	2.16
May	13,278	530	1,358	83,500	2.14	2.47	9.85
June	7,190	798	2,180	129,719	3.43	3.82	12.24
July	18,222	1,349	4,199	258,186	6.61	7.62	19.10
August	14,804	2,670	3,864	237,588	6.09	7.02	23.03
September	18,462	2,486	4,402	261,937	6.93	7.73	18.78

Estimated monthly discharge of Chagres River at Gamboa, from measurements by the Panama Canal Company—Continued.

Month.	Discharged in second feet.			Total in acre-feet.	Run-off.		Colon rainfall, inches.
	Maximum.	Maximum.	Mean.		Second-feet per square mile.	Depth in inches.	
1894.							
October	6,039	2,860	a4,690	288,370	7.38	8.51	12.40
November	21,780	....	a6,530	388,560	10.28	11.47	23.66
December	32,510	....	a10,620	653,000	16.72	19.28	25.12
The year	32,510	530	3,770	2,732,284	5.94	80.68	153.69
1895.							
January	14,610	1,910	3,530	217,050	5.56	6.41	3.86
February	3,350	1,160	1,480	82,200	2.33	2.43	1.89
March	3,210	850	1,200	73,790	1.89	2.18	2.09
April	14,120	565	1,130	67,240	1.78	1.99	21.73
May	12,430	1,760	3,210	197,380	5.06	5.83	16.77
June	25,560	1,690	2,930	174,350	4.61	5.14	9.25
July	21,000	1,410	2,860	175,850	4.50	5.19	17.09
August	19,340	2,050	3,740	229,960	5.89	6.79	14.13
September	12,140	600	3,140	186,840	4.95	5.52	12.09
October	27,990	1,690	4,590	282,230	7.23	8.34	16.46
November	....	....	3,280	195,170	5.17	5.77	20.47
December	....	....	3,280	201,680	5.17	5.96	15.71
The year	27,990	565	2,880	2,083,740	4.53	61.55	151.54
1896.							
January	....	....	2,220	136,500	3.50	4.04	4.02
February	....	....	1,130	65,000	1.78	1.92	1.30
March	....	....	a630	38,740	0.99	1.14	2.01
April	....	....	3,070	182,680	4.84	5.40	9.02
May	....	....	3,280	201,680	5.17	5.96	16.46
June	....	....	3,810	226,710	6.00	6.69	8.50
July	....	....	2,720	167,250	4.28	4.94	13.58
August	....	....	2,580	158,640	4.06	4.68	15.51
September	....	....	3,420	203,500	5.39	6.01	12.84
October	....	....	3,180	195,530	5.00	5.76	13.98
November	....	....	4,980	296,330	7.84	8.75	15.63
December	....	....	3,600	221,350	5.67	6.54	18.66
The year	....	....	2,880	2,093,910	4.53	61.83	131.51

a These means are obtained by averaging the discharge measurements.

NOTE.—Number of days lacking: In January, 5; February, 9; March, 31; April, 18; May, 7; August, 23; September, 8; October, 1; November, 9; December, 6.

Estimated monthly discharge of Chagres River at Gamboa, from measurements by the Panama Canal Company—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Colon rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1897.							
January			5,120	314,800	8.06	9.29	3.42
February			1,130	62,760	1.78	1.85	0.04
March			777	47,780	1.22	1.41	0.28
April			670	39,870	1.06	1.18	3.74
May	42,190	2,050	6,710	412,580	10.57	12.19	16.34
June	12,110	3,920	6,570	390,940	10.35	11.55	18.82
July	13,480	4,270	5,360	329,570	8.44	9.73	14.06
August			[a] 4,090	251,480	6.44	7.42	17.24
September			[a] 3,850	229,090	6.06	6.76	17.20
October	13,870	2,050	3,560	218,900	5.60	6.46	5.83
November	18,250	3,070	4,130	245,750	6.50	7.25	22.16
December	20,020	1,450	4,270	262,550	6.72	7.75	18.90
The year	42,190		3,880	2,806,070	6.11	82.84	138.03
1898.							
January	27,710	2,010	4,310	265,010	6.80	7.84	5.04
February	2,930	1,130	1,480	82,200	2.33	2.43	0.35
March	2,540	777	1,020	62,720	1.60	1.84	1.58
April	28,770	777	1,840	109,490	2.90	3.24	4.72
May	9,920	1,340	2,470	151,870	3.89	4.48	12.83
June	11,650	1,380	2,860	170,180	4.50	5.02	16.38
July	18,960	2,330	4,240	260,700	6.68	7.70	21.89
August	14,510	2,470	4,130	253,940	6.50	7.49	10.91
September	7,270	1,660	2,540	151,140	4.00	4.46	10.24
October	20,470	1,340	3,460	212,750	5.45	6.28	11.38
November	27,600	1,020	5,190	308,830	8.17	9.12	12.28
December	5,790	1,690	2,290	140,800	3.60	4.15	7.95
The year	28,770	777	3,000	2,169,630	4.72	64.05	115.55
1899.							
January	22,060	1,730	3,490	214,600	5.50	6.34	6.93
February			950	52,760	1.50	1.56	6.49
March			950	58,410	1.50	1.73	1.26
April	6,740	706	1,060	63,070	1.67	1.86	0.43
May	20,470	706	1,910	117,440	3.00	3.46	13.90
June	14,120	1,310	2,470	146,970	3.89	4.34	6.41

[a] These means are obtained by averaging the discharge measurements.

Estimated monthly discharge of Chagres River at Gamboa, from measurements by the Panama Canal Company—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Colon rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1899.							
July	14,120	1,340	2,820	173,400	4.44	5.12	27.68
August	26,190	1,870	4,240	260,700	6.68	7.70	14.80
September	11,750	1,660	3,180	189,220	5.00	5.58	16.55
October	13,730	1,840	3,390	208,440	5.34	6.16	15.04
November	23,890	1,870	3,740	222,550	5.89	6.57	14.49
December	13,200	1,620	2,650	162,940	4.17	4.81	9.04
The year	26,190	706	2,580	1,870,500	4.06	55.23	133.02
1900.							
January	12,920	1,060	1,690	103,910	2.66	3.07	2.09
February	1,165	600	810	44,980	1.28	1.33	0.35
March	670	424	530	32,590	0.83	0.96	0.29
April	1,870	388	565	33,620	0.89	0.99	3.94
May	12,320	424	1,340	82,400	2.11	2.43	11.15
June	10,020	918	1,940	115,440	3.06	3.41	15.94
July	16,910	1,480	3,350	205,980	5.27	6.08	14.47
August	20,620	1,620	3,565	219,200	5.61	6.47	12.43
September	16,060	1,450	3,070	182,680	4.83	5.39	14.69
October	23,720	2,050	4,520	277,920	7.12	8.21	15.78
November	17,540	1,910	4,060	241,590	6.40	7.14	13.86
December	21,920	1,160	2,680	164,790	4.22	4.87	3.02
The year	23,720	388	2,360	1,705,100	3.72	50.35	108.01

Estimated monthly discharge of Chagres River at Gamboa, from observations of the Isthmian Canal Commission.

[Drainage area, 635 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfa. in basin, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1900.							
January	14,030	889	2,026	124,570	3.19	3.66	2.09
February	1,420	726	970	53,870	1.53	1.59	0.35
March	805	509	641	39,410	1.01	1.16	0.29
April	1,745	443	637	37,900	1.00	1.11	3.94
May	15,900	492	1,615	99,300	2.54	2.91	11.15
June	12,550	1,205	2,426	144,360	3.82	4.25	15.94
July	21,980	2,058	4,104	252,350	6.62	7.62	14.47
August	26,300	2,222	4,692	288,500	7.39	8.51	12.43
September	20,060	1,899	3,750	223,140	5.91	6.59	14.69
October	29,900	2,795	5,846	359,460	9.21	10.61	15.78
November	22,760	2,461	5,415	322,220	8.53	9.52	13.86
December	27,900	1,509	3,380	207,830	5.32	6.13	3.02
The year	29,900	443	2,974	2,152,910	....	63.66	108.01

Ratio of run-off to rainfall=59 per cent.

TRIBUTARIES BETWEEN BOHIO AND GAMBOA.

The largest tributary between Bohio and Gamboa is the Caña Quebrada. Minor tributaries in order of their size are the Obispo, Gigante, Frijoles, and Frijolitos, and Agua Salud. By subtracting the mean monthly discharge of the Chagres at Gamboa from the discharge at Bohio the discharge of all the tributaries was obtained.

Estimated monthly discharge of tributaries to the Chagres River between Gamboa and Bohio.

[Drainage area, 245 square miles.]

Month.	Mean discharge in second-feet.	Total in acre-feet.	Run-off.		[a] Rainfall, inches.
			Second-feet per square mile.	Depth in inches.	
1900.					
January	177	10,890	0.72	0.83	3.57
February	82	4,550	0.33	0.34	0.26
March	40	2,460	0.17	0.20	0.46
April	15	900	0.06	0.07	3.08
May	55	3,380	0.22	0.25	7.08
June	759	45,160	3.10	3.46	11.01
July	1,856	114,120	7.57	8.73	16.99
August	1,188	73,050	4.85	5.59	11.33
September	1,440	85,690	5.88	6.56	11.96
October	2,374	145,970	9.69	11.17	15.27
November	2,125	126,440	8.68	9.68	17.82
December	720	44,270	2.94	3.39	2.40
The year	908	656,880	....	50.27	101.23

[a] Mean of observations at Bohio, Gorgona, and Gamboa.

Ratio of run-off to rainfall=50 per cent.

The tributaries named below were gaged on an average of once a week, and the following table depends upon these data:

Measurements of flow of tributaries of Chagres River.

River.	Maximum measured discharge.	Minimum measured discharge.	Mean.	Per cent of total discharge.[a]
	Sec. ft.	*Sec. ft.*	*Sec. ft.*	
Caña Quebrada	1,640	17	335	37
Obispo	1,177	1	90	10
Gigante	281	0	65	7
Frijoles and Frijolitos	219	5	55	6
Agua Salud	90	3	33	4
Other sources	....	....	330	36
Total	....	....	908	100

[a] The last column indicates the per cent of the total inflow between Gamboa and Bohio contributed by each stream.

BOHIO STATION ON CHAGRES RIVER.

The present plans of both the Isthmian Canal Commission and the Panama Canal Company provide for a dam at Bohio. The company established a fluviograph here in 1895 and a record of discharge has been kept ever since.

The Canal Company's gaging station is at Buena Vista, about one-half mile above the proposed dam site. It is on a long, straight stretch of the river, 220 feet wide, with high, steep banks. The cross sections are very similar and the velocities across the stream are very uniform. It is almost an ideal station for discharge measurements, its sole defect being that at times of extreme low water the tides of the Atlantic may slightly affect the velocity.

The fluviograph is at Bohio and is the counterpart of the one at Alhajuela, but the tides are noticeable whenever the height of the river is less than 0.5 meter, so that below this stage a rating table may give slightly erroneous results, as the same gage height at different times may not correspond to the same discharge. A gage rod divided into centimeters is firmly set in the bank at the gaging station. The reading of this is used in obtaining the mean area of cross section.

Annual summary of discharge measurements made by the Panama Canal Company at Bohio.

Year.	Maximum.	Minimum.	Mean.	Total in acre-feet.	Run-off.		Rainfall at Colon.
					Second-feet per square mile.	Depth in inches.	
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*				
1895	27,750	710	4,510	3,263,810	5.12	69.52	151.54
1896	28,950	600	4,220	3,062,960	4.80	65.28	131.51
1897	38,790	495	4,850	3,514,390	5.51	74.88	138.03
1898	27,890	780	3,960	2,865,730	4.50	61.07	115.55
1899	25,870	600	3,400	2,458,420	3.86	52.40	133.02
1900	23,860	490	3,520	2,551,810	4.00	54.38	108.67

Estimated monthly discharge of Chagres River at Bohio, from observations of Panama Canal Company.

[Drainage area, 880 square miles.]

Months.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1895.						
January	20,721	2,290	[a] 4,550	279,770	5.17	5.96
February	2,930	1,900	[a] 1,380	76,640	1.57	1.63
March	....	....	[a] 1,060	65,180	1.20	1.38
April	11,540	710	[a] 1,060	63,070	1.20	1.34
May	13,830	1,380	[a] 4,170	256,400	4.74	5.46
June	10,770	2,290	[a] 4,310	256,460	4.89	5.46
July	19,980	1,910	[a] 4,590	282,230	5.22	6.02
August	15,500	1,940	[a] 6,920	425,500	7.86	9.06
September	21,320	2,540	[a] 5,790	344,530	6.58	7.34
October	27,750	2,610	[a] 6,920	425,500	7.86	9.06
November	18,640	4,020	[a] 6,070	361,190	6.90	7.70
December	27,180	2,610	[a] 6,950	427,340	7.90	9.11
The year	27,750	710	4,510	3,263,810	5.12	69.52
1896.						
January	10,450	1,910	[a] 4,730	290,840	5.38	6.20
February	2,470	1,020	[a] 1,550	89,160	1.76	1.90
March	1,940	740	[a] 880	54,110	1.00	1.15
April	25,030	600	[a] 1,690	100,570	1.92	2.14
May	16,270	1,730	[a] 4,940	303,750	5.61	6.47
June	13,240	2,080	[a] 4,200	249,920	4.77	5.32
July	22,950	2,430	[a] 3,140	193,070	3.57	4.12
August	11,930	2,650	[a] 3,500	215,200	4.00	4.61
September	....	....	[a] 5,930	352,860	6.74	7.52
October	....	....	[a] 6,350	390,450	7.22	8.32
November	19,100	....	[a] 7,590	451,640	8.62	9.62
December	28,950	3,880	[a] 6,040	371,390	6.86	7.91
The year	28,950	600	4,220	3,062,960	4.80	65.28
1897.						
January	5,370	3,390	[a] 2,050	126,050	2.33	2.69
February	....	....	[a] 1,590	88,300	1.81	1.88
March	1,380	600	[a] 710	43,660	0.81	0.93
April	14,160	495	[a] 880	52,360	1.00	1.12
May	38,790	850	[a] 7,980	490,670	9.07	10.46
June	12,910	3,460	[a] 4,200	249,920	4.77	5.32
July	17,400	2,860	[a] 5,120	314,820	5.82	6.71

[a] These means are obtained by averaging the discharge measurements.

Estimated monthly discharge of Chagres River at Bohio, from observations of Panama Canal Company—Continued.

Months.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1897.						
August	18,460	2,820	[a] 7,270	447,010	8.26	9.52
September	21,110	4,130	[a] 6,880	409,390	7.82	8.72
October	17,540	3,390	[a] 7,480	459,930	8.50	9.80
November	22,100	3,810	[a] 6,950	413,550	7.90	8.81
December	22,100	3,670	[a] 6,810	418,730	7.74	8.92
The year	38,790	495	4,850	3,514,390	5.51	74.88
1898.						
January	27,250	2,260	5,650	347,400	6.42	7.40
February	3,320	1,230	1,690	93,860	1.92	2.00
March	2,400	810	1,090	67,020	1.24	1.43
April	24,000	780	2,010	119,600	2.28	2.54
May	8,510	1,450	2,680	164,790	3.05	3.52
June	15,140	1,760	3,350	199,340	3.81	4.25
July	23,860	2,890	6,570	403,970	7.47	8.61
August	15,500	3,000	5,300	325,880	6.02	6.94
September	8,540	2,150	3,210	191,000	3.65	4.07
October	23,370	2,080	5,050	310,510	5.74	6.62
November	27,890	3,810	7,840	466,510	8.91	9.94
December	6,670	1,980	2,860	175,850	3.25	3.75
The year	27,890	780	3,960	2,865,730	4.50	61.07
1899.						
January	22,240	1,800	3,848	236,600	4.37	5.04
February	2,540	1,340	1,730	95,960	1.98	2.06
March	1,410	740	988	60,750	1.12	1.29
April	3,280	635	1,090	64,860	1.24	1.38
May	17,540	600	2,050	126,050	2.33	2.69
June	5,470	1,910	3,140	186,840	3.57	3.98
July	17,750	1,660	3,950	242,880	4.49	5.18
August	25,870	3,040	5,720	351,700	6.50	7.49
September	9,531	2,440	4,240	252,300	4.82	5.38
October	16,130	2,720	4,940	303,750	5.61	6.47
November	24,250	2,790	5,300	315,370	6.02	6.72
December	15,280	940	3,600	221,360	4.09	4.72
The year	25,870	600	3,400	2,458,420	3.86	52.40

[a] These means are obtained by averaging the discharge measurements.

Estimated monthly discharge of Chagres River at Bohio, from observations of Panama Canal Company—Continued.

[Drainage area, 880 square miles.]

Months.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall in basin, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1900.							
January	10,410	1,480	2,120	130,350	2.41	2.78	2.44
February	1,380	810	1,060	58,870	1.20	1.25	0.33
March	920	600	740	45,500	0.84	0.97	0.32
April	1,765	490	706	42,010	0.80	0.89	3.78
May	9,672	490	1,620	99,610	1.84	2.12	10.45
June	10,840	1,340	2,860	170,180	3.25	3.63	15.67
July	21,180	2,010	5,610	344,940	6.38	7.36	15.28
August	19,240	2,440	5,260	323,420	5.98	6.89	12.36
September	18,070	2,260	4,770	283,830	5.42	6.05	14.33
October	23,860	3,180	7,000	430,410	7.95	9.17	15.48
November	20,300	3,740	6,600	392,730	7.50	8.37	15.10
December	22,870	1,800	3,740	229,960	4.25	4.90	3.13
The year	23,860	490	3,520	2,551,810	4.00	54.38	108.67

Estimated monthly discharge of Chagres River at Bohio based on discharge measurements made by the Isthmian Canal Commission.

[Drainage area, 880 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Colon rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1899.							
January	21,830	1,900	4,150	255,170	4.72	5.44	6.93
February	2,810	1,300	1,795	99,690	2.04	2.12	6.49
March	1,420	665	943	57,980	1.07	1.23	1.26
April	3,670	570	1,057	62,900	1.20	1.34	.43
May	17,440	540	1,900	116,830	2.16	2.49	13.90
June	6,440	2,030	3,500	208,260	3.98	4.44	6.41
July	17,730	1,710	4,372	268,820	4.97	5.73	27.68
August	24,520	3,370	6,425	395,060	7.30	8.42	14.80
September	10,225	2,680	4,858	289,070	5.52	6.16	16.55
October	16,285	2,990	5,511	338,860	6.26	7.22	15.04
November	23,320	3,080	5,732	341,080	6.51	7.26	14.49
December	15,430	2,210	3,950	242,880	4.49	5.18	9.04
The year	24,520	540	3,697	2,676,600	4.18	57.03	133.02
1900.							
January	10,155	1,441	2,203	135,460	2.50	2.87	2.44
February	1,640	802	1,052	58,420	1.20	1.24	0.33
March	877	570	681	41,870	0.77	0.88	0.32
April	1,845	442	652	38,800	0.74	0.82	3.78
May	9,500	506	1,670	102,680	1.92	3.20	10.45
June	12,700	1,640	3,185	189,520	3.62	4.04	15.67
July	20,650	2,521	5,960	366,470	6.77	7.80	15.28
August	18,900	2,859	5,880	361,550	6.68	7.70	12.36
September	17,800	2,651	5,190	308,830	5.90	6.58	14.33
October	23,000	3,802	8,220	505,430	9.34	10.77	15.48
November	19,800	4,464	7,540	448,660	8.57	9.56	15.10
December	22,100	1,949	4,100	252,100	4.66	5.37	3.13
The year	23,000	442	3,880	2,809,790	....	60.83	108.67

Ratio of run-off to rainfall =56 per cent.

HYDRAULICS OF CHAGRES RIVER AT ALHAJUELA AND BOHIO

At Alhajuela and Bohio the fluviograph rods and gage rods were read each time a gaging was made. The difference in these simultaneous readings in connection with the distance between the rods, the

measured discharge, and the several cross sections of the river furnished the slope, the mean hydraulic radius, and the mean velocity. From these data the value of the coefficient for roughness, "n," in Kutter's formula, was computed, and the results are shown in the table below.

At Alhajuela the distance between the rods is 200 meters. The bed of the river is small gravel, and the banks are steep and free from weeds and bushes. At Bohio the distance between the rods is 1,335 meters. The bed is clay with small gravel and is free from detritus. The banks are high, but are covered with weeds and bushes.

Hydraulic observations on Chagres River.

ALHAJUELA.

Gage height.	Mean area.	Mean discharge.	Mean velocity.	Hydraulic radius.	Slope.	"n."
Meters.	*Sq. ft.*	*Sec. ft.*	*Ft. per sec.*			
28.15	815	580	0.71	3.84	0.000025	0.027
28.28	910	953	1.05	4.16	0.000050	0.026
28.51	1,075	1,928	1.80	4.74	0.000095	0.023
28.68	1,200	2,926	2.44	5.17	0.000144	0.022
28.84	1,320	4,040	3.01	5.58	0.000211	0.023
29.46	1,785	9,361	5.20	7.23	0.000350	0.020
31.01	3,000	25,872	8.62	11.50	0.000892	0.026
BOHIO.						
1.59	1,340	2,560	1.91	5.90	0.000097	0.025
2.50	2,000	6,100	3.05	8.58	0.000142	0.024
3.19	2,500	8,930	3.58	10.42	0.000165	0.026
4.42	3,400	14,600	4.29	13.10	0.000210	0.029
5.50	4,040	21,020	5.20	14.70	0.000277	0.029

TRINIDAD AND GATUN RIVERS.

Below Bohio the major part of the Chagres flows through the almost completed cut for the canal, its old channel being in many places choked by vegetation; in this stretch it receives the waters of two large tributaries, the Trinidad, and the Gatun. Frequent trips to these were made and current meter measurements were made each time. No gage rods were set on these streams, because if they were set less than 10 miles up, the slope of the rivers being very slight, the fluctuations of the Chagres would materially influence the rod-reading, and the time taken in these trips would be longer than the time taken in making a gaging; the inflow between the mouth and the station would also be omitted.

Discharge of the Gatun and Trinidad rivers.

GATUN.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
1899.	*Sec.-ft.*	1900.	*Sec.-ft.*	1900.	*Sec.-ft.*
November 17	1,213	March 12	142	June 11	348
December 9	688	March 15	111	June 14	285
December 29	442	March 19	164	June 18	214
1900.		March 23	133	June 21	225
January 11	359	March 26	178	June 28	616
January 19	218	April 5	130	July 5	945
January 25	259	April 12	88	July 9	1,569
February 1	209	April 17	133	July 12	916
February 6	216	April 20	98	July 16	962
February 8	198	April 23	117	July 19	729
February 12	160	April 26	237	July 25	925
February 15	151	May 3	71	August 2	922
February 22	160	May 14	65	August 24	1,021
February 26	186	May 18	225	September 5	420
March 1	109	May 21	240	September 11	1,111
March 6	197	May 30	217	September 18	888
		June 7	315		

	Second feet.
Maximum	1,569
Minimum	65
Mean	528

TRINIDAD.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
1899.	*Sec.-ft.*	1900.	*Sec.-ft.*	1900.	*Sec.-ft.*
November 17	1,687	March 6	368	June 21	1,358
December 9	2,371	March 15	143	June 28	1,537
December 29	896	March 19	242	July 2	1,337
1900.		March 23	221	July 5	1,577
January 8	1,210	March 26	304	July 9	1,574
January 11	744	April 12	204	July 12	1,868
January 15	705	April 17	226	July 16	1,594
January 19	574	April 20	220	July 19	2,255
January 22	599	April 23	225	July 25	2,295
January 25	569	May 1	261	August 2	2,144
January 29	555	May 3	286	August 7	1,375
February 1	631	May 10	463	August 24	1,464
February 6	439	May 14	244	August 30	2,521
February 8	492	May 18	610	September 5	1,403
February 12	450	May 21	620	September 8	1,283
February 15	291	May 24	533	September 11	2,120
February 19	299	May 30	1,094	September 18	2,607
February 22	264	June 7	2,373	September 21	1,474
February 26	358	June 11	1,379	September 27	2,256
March 1	365	June 14	993		
		June 18	931		

	Second feet.
Maximum	2,607
Minimum	143
Mean	1,100

The "mean" is the mean of the monthly means.

FLOODS OF THE CHAGRES RIVER.

The projected canal from Colon to Panama is 47 miles in length and for more than half this distance it follows the valley of the Chagres. Where it leaves this valley to cut through the continental divide the river bed is at an elevation of nearly 50 feet. If the river were taken into a sea-level canal it would form a cataract nearly 50 feet high at this point, which would of course be inadmissible; so that for a sea-level project it would be necessary to construct an enormous channel capable of carrying the flood waters of the Chagres River to the sea independent of the canal and the same would be necessary with all the principal tributaries. It is now generally conceded that for this reason a sea-level canal is impracticable. The magnitude of a flood discharge, however, remains important in its relation to the works necessary for controlling and discharging the surplus waters without injury to the works or obstruction to navigation.

Although nearly the entire country is clothed with vegetation, much of which is very dense, the slopes are so precipitous and rock is so near the surface that the heavy tropical rainfall often produces sudden freshets in the river. A violent rainfall of a few hours converts the banks of the Chagres in the vicinity of Alhajuela and above into a series of small torrents and cascades, causing the river to rise very suddenly and flow with great velocity. It is this feature that lends such importance to the study of the floods of the Chagres in their relation to the proposed canal.

It is stated by the officers of the Panama Railway Company that previous to 1879 no freshet had occurred in the Chagres of magnitude sufficient to cause serious damage to the property of the railway company or to delay its operations. The flood of 1879 caused great damage to the railway and obstructed traffic for a considerable period, and the conclusion follows that it is far greater than any flood that had occurred since the construction of the railway was begun. This conclusion is verified by the testimony of the oldest inhabitants of the region.

Since 1879 sufficient attention has been paid by canal officials to render it certain that no flood equal in magnitude to that of 1879 has since occurred. The flood occurred in November, but we do not know how long it lasted, except that a violent storm raged for six days throughout the Isthmus, the precipitation amounting to 320 millimeters at Panama. De Lesseps and his associates made no mention whatever in their journals or other records of this matter, so vital to their project of a sea-level canal, but, on the contrary, their efforts seem to have been to prevent public knowledge of its magnitude.

The only actual information existing other than that of a general character from the officials of the Panama Railway, above referred to, is the testimony of Mr. Sosa, a young Colombian engineer, who by

inquiry from the inhabitants, or otherwise, decided upon certain points as high water of this flood in the neighborhood of Bohio. Mr. Sosa was unfortunately drowned in the sinking of *La Bourgogne*, and it is not known how accurate his information was, excepting that he expressed his entire reliance upon it. By his testimony the river reached an elevation of 12 meters above sea level at Bohio at its maximum stage. From the measurements made of the floods of less magnitude, and from the large number of measurements of the river at its lower stage a curve has been plotted expressing the relation of discharge and gage height at Bohio. The existing observations are in satisfactory accordance, and by extrapolating this curve upward to include the flood of 1879 we obtain a discharge for the river at Bohio for gage height 12 meters of 3,860 cubic meters, or about 136,000 cubic feet per second, and is submitted as being the best conclusion permitted. The observations are those given by General Abbot in his note "Sur le régime du Chagres," pages 24 to 27. The results obtained by the company at Bohio being in practical accordance with those observed by the commission are accepted without change.

In this connection three points should be remembered: First, the discharge for "cote" 12 may be greater than here indicated; second, the flood of 1879 may have reached a higher elevation than "cote" 12; third, it is possible that a larger flood than that of 1879 may occur in the future.

Under these circumstances it seems safe to consider the maximum flood wave to be expected on the Chagres at about 140,000 cubic feet per second.

Four great floods occurred since 1879, of which the discharge at Gamboa has been measured or estimated by the Panama Canal Company as follows:

Discharge of floods at Gamboa.

Date.	Gage height.	Discharge (maximum).	Mean for 48 hours.	Percentage.
	Meters.	*Cu. meters.*	*Cu. meters.*	
November 25, 1885	23.60	1,638	1,077	66
December 12, 1888	23.56	1,628	1,270	78
December 1, 1890	23.70	1,663	833	50
December 17, 1893	21.72	1,207	759	63

The flood of 1879 seems to have been longer sustained than any of the others, and it seems likely that the ratio of the mean discharge to the maximum should be somewhat greater than the others. General Abbot has assumed the mean discharge for this flood at 80 per cent of the maximum, and this appears to be approximately correct. Eighty per cent of 140,000 cubic feet per second is 112,000 cubic feet per second.

The area of Lake Bohio, according to the plans adopted by the Commission, is as follows:

Area of Lake Bohio.

Elevation.	Acres.	Square miles.
20 meters (65.6 feet)	14,771	23.08
25 meters (82 feet)	23,542	36.78
26 meters (85.3 feet)	24,627	38.48

The waste weir provided is to be at an elevation of 85 feet above sea level, or slightly less than 26 meters, and is to have a length of 2,000 feet.

This flow continued for 48 hours would result in a total discharge of 44,300 acre-feet, or about 9,300 acre-feet per hour. A sustained discharge of this amount would raise the lake to a head of about 6.6 feet over the sill of the weir. This, however, may be taken as the extreme condition which will never be exceeded.

LOW WATER OF THE CHAGRES RIVER.

The Chagres River being the one feeder to the summit level of the proposed canal, its mean and minimum flow is very important as indicating the amount of storage that must be provided for the operation of the canal during the dry season. The mean flow for the various months of the year, as determined by averaging all the monthly records in our possession since 1892, is as follows:

Mean flow of the Chagres River.

	Sec.-ft.
January	2,948
February	1,357
March	958
April	1,555
May	3,252
June	3,063
July	4,006
August	4,404
September	3,628
October	4,237
November	4,785
December	4,408

Averaging these quantities we find the mean annual discharge is about 3,200 cubic feet per second. As the maximum consumption and loss by leakage and evaporation is estimated at 1,000 cubic feet per second, we find that the month of March is the only month having a shortage in average years; and as this is the record for Gamboa, and the discharge at Bohio, where the dam is to be constructed, is somewhat greater, we may say that the requirements of the canal are less than the average discharge for any month in the year, and if one-third

of the mean annual flow can be saved there will be ample for canal purposes.

But some years furnish less water than others, and to correctly solve the problem of the water supply for the canal we must consider the yield in the minimum year.

In all the observations at Bohio the lowest monthly means are for the months of March and April, 1891, as shown by the mean of eight measurements made in each of those months. More records, however, are at hand for Gamboa than for Bohio, and the lowest reading at the Gamboa fluviograph occurred in the spring of 1900, when, for a period of about two months, the fluviograph at Gamboa indicated a stage of less than 14 meters almost continuously, the lowest point reached being 13.82. This corresponds to a discharge of from 15 to 20 cubic meters per second.

In the examination of the records in Paris an elevation at Gamboa was found for the last three days of March, 1896, giving the stage as 13.1 meters. The rest of the month of March and the first half of April are entirely blank, no record having been kept. It is impossible that this could have been a flüviograph record, since the river would be dry before reaching so low an elevation at the location of the fluviograph, and the only plausible explanation is that given by the officers of the company, that this record was on a rod a considerable distance below the fluviograph; and this statement is confirmed by the reports of discharge on these dates, which are 16.8, 16.8, and 16.9 cubic meters, respectively, leaving no doubt that at this time the river was above the stage reached in 1900. No other record gives a stage of river as low as that reached in 1900.

The year 1891, however, seems to have had a still lower dry-season flow. No fluviograph records were obtainable except such as were given with the measurements of discharge, and these do not show any stage as low as that of 1900; but in so long a time the bed of the river would be likely to change, and the measurements show that it has done so. Of actual gagings we have (page 604) eight for February, eight for March, and eight for April. The measurement on the 1st of May shows low water, while that of May 4 exhibits a freshet.

The indications of the gagings are that up to February 14 the discharge of the river was above the requirements of the canal, while from February 15 to May 3 they were below. This is the same period for which eight measurements per month were made at Bohio. The means are 39 cubic meters per second for February, 17 for March, and 17 foı April. This is the lowest discharge at Bohio of which we have record. It is, of course, not certain that a drier year has not occurred, or will not occur, and in making the estimates it will be assumed that the mean of 17 cubic meters, or 600 cubic feet, per second is continuous for ninety days, from February 1 to May 1.

The requirements and losses of the canal in operation, as estimated by this Commission, are as follows:

Water required by Panama Canal.

	Cubic ft. per sec.
Lockage	406
Power	200
Leakage	257
Evaporation	207
Total	1,070

Applying this quantity, we have for the 90 days from February 1 to May 1—

	Acre-feet.
Total leakage, lockage, and evaporation, 1,070 cubic feet per second	191,000
Less inflow	107,000
Deficit	84,000

Taking 24,000 acres as the area of the lake, this will lower the lake about 3.5 feet. An allowance of this amount is therefore ample for the most extreme case.

This brings the elevation of the lake to 81.5 feet, which may be regarded as the elevation reached in the minimum year of a long series, and would occur perhaps only once in a generation. If the consumption and loss should be less than 1,070 cubic feet per second, the deficit would, of course, be diminished.

The dry season of 1900 would have brought the lake level to an elevation of about 82.5.

The possibility always remains of constructing a large reservoir at Alhajuela, which will not only guard against annoying currents in Lake Bohio, but will store sufficient water for use in the dry season, so that the lake need never decline below the sill of the wastewier.

It is indeed true, as stated by General Abbot, that the Chagres is a river well adapted to the service of the proposed Panama canal.

SEDIMENT OBSERVATIONS.

Observations to determine the amount of sediment carried by the Chagres River were made at Alhajuela and Bohio by means of water samples representing the mean condition of the river.

Month.	Alhajuela.		Bohio.	
	Mud.	Solid matter.	Mud.	Solid matter.
1900.	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*
May				
June	75,900	15,180	152,720	30,540
July			763,800	152,760
August	406,100	81,230	580,000	116,000
September	208,300	41,660	396,800	79,360
October	485,040	97,000		

NOTE.—Five cubic yards of mud are assumed to equal 1 cubic yard of solid matter.

PACIFIC SLOPE.

In a minor degree it is required to know something of the volume and regimen of the Grande River, which is followed by the canal line from Paraiso to the Pacific, and which is the only stream near the canal on that slope.

GRANDE RIVER.

From Culebra to the Pacific Ocean the line of the canal follows the valley of the Grande River, therefore an idea of the floods and the general characteristics of this stream becomes valuable; accordingly, on October 25, 1899, two gage rods were set at Pedro Miguel, the first being 250 yards above and the second 30 yards below the mouth of the Pedro Miguel River. The lower rod could not be set farther downstream on account of the high tides of the Pacific Ocean, the tidal effect at Miraflores being at least 5 feet.

These rods were read at 6 a. m. and 6 p. m., and additional readings were taken during floods.

Estimated monthly discharge of Grande River at 250 yards above the mouth of the Pedro Miguel.

[Drainage area, 10 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1899.							
November	410	10.0	35.0	2,082	3.50	3.90	8.67
December	65	3.0	13.0	800	1.30	1.50	2.34
1900.							
January	37	1.0	3.0	184	0.30	0.35	0.56
February	1	0.5	0.7	39	0.07	0.07	0.09
March	2	0.0	0.2	12	0.02	0.02	0.00
April	1	0.0	0.3	18	0.03	0.03	2.73
May	210	0.6	11.0	676	1.10	1.27	10.66
June	650	3.0	44.0	2,618	4.40	4.91	10.30
July	550	5.0	114.0	7,010	11.40	13.14	25.04
August	283	2.0	50.0	3,074	5.00	5.76	6.52
September	660	11.0	38.0	2,261	3.80	4.24	6.75
October	370	30.0	60.0	3,690	6.00	6.92	8.68
November	....	....	....	....	....	....	....
December	....	....	....	....	....	....	....
The year	660	0.0	31.0	22,464	....	42.11	82.34

Ratio of run-off to rainfall = 0.51 per cent.

Estimated monthly discharge of Grande River at 30 yards below the mouth of Pedro Miguel River.

[Drainage area, 19 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall, inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1899.							
November	790	27.0	81.0	4,820	4.26	4.75	8.67
December	100	12.0	26.0	1,600	1.37	1.58	2.34
1900.							
January	50	3.0	7.0	430	0.37	0.43	0.56
February	3	0.0	1.0	56	0.05	0.05	0.09
March	3	0.0	0.2	12	0.01	0.01	0.00
April	2	0.0	0.5	31	0.03	0.03	2.73
May	310	1.0	24.0	1,476	1.26	1.45	10.66
June	1,550	10.0	105.0	6,250	5.53	6.17	10.30
July	1,850	21.0	295.0	18,140	15.53	17.90	25.04
August	1,550	12.0	142.0	8,730	7.47	8.61	6.52
September	1,550	18.0	80.0	4,760	4.21	4.70	6.75
October	800	34.0	112.0	6,885	5.90	6.80	8.68
The year	1,550	0.0	74.0	53,190	....	52.48	82.34

Ratio of run-off to rainfall = 0.637 per cent.

RAINFALL.

Notwithstanding the fact that the Isthmus is narrow and the cordillera low in the vicinity of Panama there is a striking difference of rainfall between the Caribbean or northern, and the Pacific or southern coast of the Isthmus in this region. The contrast is similar to that between the east and west coasts of Nicaragua, though not so striking. The mean rainfall at Colon, as shown by a record of nearly thirty years, is 130 inches, while that at Panama, though not so well determined, is only 66.8. The precipitation at Panama and vicinity is confined almost entirely to the months from May to November, inclusive. The rest of the year is the dry season. At Colon, though the rainfall is less during the dry season, there is still considerable precipitation, the mean for April being 4.54, and for January 3.73, while these two months are dry on the Panama side. February and March are less likely to yield any considerable precipitation, but no month is exempt from rainfall on the coast of the Caribbean. The upper portion of the Chagres drainage basin represents the mean between these extremes.

The longest record of rainfall in the vicinity is that of Colon, which has been kept continuously from March, 1881, to date, with the exception of a period of twenty-one months in 1888–1889. This station, however, is not on the Chagres drainage, and the records kept in that basin do not cover so long a period. They are mainly at Gamboa and Obispo, with very short records at Bohio, Gorgona, and Alhajuela. Short records also exist at Panama, at La Boca, the south end of the canal, and at Naos, an island in the bay of Panama.

The long records of stream flow at Gamboa and Bohio, together with an approximate knowledge of the area of the drainage basin and the observations of rainfall, constitute a valuable contribution to the knowledge of the ratio of rainfall to run-off in the Tropics, the weakest point being the information on rainfall, the only records in the basin being confined to the lower valley, and being, moreover, very short. If a definite relation could be established between the long Colon record and the mean of the Chagres Basin, it would increase the value of these data to an important extent. For this purpose five stations above Alhajuela were established in 1899, two at different points on Rio Pequeni at Salamanca and Las Minas, one on the Upper Chagres at Santa Barbara, and two at high elevations above the river valley. Of the latter, one is on a hill between the Chagres and Pequeni, 700 feet above the nearest point of the Chagres, and the other is between the Chagres and Puento, about 500 feet above the river. Salamanca and Las Minas were discontinued at the end of 1900. The others were discontinued October 30, 1900. Their relative location is shown on the map, page 530. These stations, considered with those lower in the basin, are taken as the mean for the basin and compared with observations at Colon, as follows:

Rainfall on Isthmus of Panama, 1900, in inches.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Colon	6.06	0.33	1.06	0.75	12.25	11.65	16.81	17.04	9.37	16.33	20.28	4.13	116.06
Bohio	7.06	0.48	1.04	2.89	7.42	18.40	17.79	14.02	15.40	18.43	24.98	4.02	131.93
Gorgona	2.63	0.13	0.20	3.15	7.07	12.48	19.72	11.04	11.25	11.93	......	......	......
Gamboa	1.01	0.16	0.13	3.21	6.76	12.15	13.45	8.92	9.24	12.11	10.67	0.79	78.60
Pedro Miguel	0.56	0.09	0.00	2.73	10.66	10.30	25.04	6.52	6.75	8.68	[a]8.67	[a]2.34	82.34
Alhajuela	1.82	0.04	0.03	4.10	10.16	17.79	19.73	10.56	17.20	13.26	13.36	1.14	109.19
Campanas	1.54	0.05	0.11	2.66	8.57	22.12	12.78	12.49	13.55	15.34	......	......	......
Santa Barbara	1.41	0.16	0.09	5.43	13.67	22.54	13.65	12.65	15.66	11.80	[b]13.50	[a]2.62	113.18
Rio Fea	1.26	0.26	0.11	5.60	12.64	20.48	13.41	9.79	16.51	21.98	......	[a]2.06	......
Rio Puente	1.02	0.12	0.08	1.61	10.11	19.35	18.14	20.09	15.50	15.15	......	[a]1.81	......
Salamanca	3.20	0.50	0.38	3.22	12.15	8.37	10.46	9.97	18.81	16.20	14.77	2.92	100.95
Las Minas	4.90	1.17	1.21	4.39	12.53	10.91	12.43	15.01	9.90	19.91	16.63	7.23	116.22

[a] For 1899. [b] Estimated.

Rainfall at Colon, in inches, compared with mean rainfall in basin of Chagres River.

Month.	Colon.				Chagres Basin.
	Maximum, 1872.	Minimum, 1884.	1900.	Mean for thirty years.	1900.
January	3.57	3.39	6.06	3.56	2.44
February	0.75	0.39	0.33	1.52	0.33
March	0.83	0.39	1.06	1.55	0.32
April	1.30	4.33	0.75	4.42	3.78
May	21.43	10.16	12.25	12.27	10.45
June	22.00	10.32	11.65	13.46	15.67
July	19.90	15.59	16.81	16.92	15.28
August	19.97	13.27	17.04	15.53	12.36
September	16.20	9.37	9.37	12.77	14.33
October	30.32	8.66	16.33	14.20	15.48
November	19.11	7.05	20.28	20.56	15.10
December	13.12	3.62	[a] 9.04	12.49	[a] 3.59
Total	168.50	86.54	120.97	129.25	109.13

[a] To obtain a comparison for a complete year the rainfall for December, 1899, is included, because during December, 1900, many stations in the basin were discontinued.

Mean rainfall on basin, 129.25, 109.13, 120.97, or 116.60 inches.

Monthly rainfall at Colon, in inches.

[1862–1874 by Drs. White and Kluge, surgeons Panama Railway Company; 1881–1898 by Panama Canal Company; 1898–1900 by Panama Railroad Company.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1862	......	......	......	......	......	......	......	......	......	13.10	43.01	16.83	......
1863	1.75	2.94	0.85	4.70	13.09	15.32	25.76	10.84	15.54	11.22	17.59	15.21	134.31
1864	1.90	0.77	0.78	0.44	15.87	8.78	16.54	13.37	17.85	12.83	17.90	16.40	123.43
1865	1.10	1.08	0.02	3.89	9.22	16.85	9.61	18.39	8.55	9.69	22.16	5.58	106.14
1866	3.99	1.07	0.21	4.07	14.76	12.17	16.72	12.72	18.82	15.04	21.72	8.42	129.71
1867	1.56	0.80	0.48	1.20	11.88	8.85	16.03	19.82	5.35	20.50	......	......	......
1868	1.17	2.77	2.18	0.87	7.24	18.11	20.60	12.50	16.16	13.13	21.58	3.72	120.03
1869	0.83	0.77	0.49	5.04	6.72	10.66	18.22	14.02	8.98	14.82	24.13	10.10	114.78
1870	4.30	3.33	4.95	6.46	20.95	12.48	15.60	16.35	6.74	11.21	32.42	14.85	149.64
1871	15.42	0.53	0.05	1.52	1.63	7.70	23.27	11.56	8.00	12.58	12.38	4.94	99.58
1872	3.57	0.75	0.83	1.30	21.43	22.00	19.90	19.97	16.20	30.32	19.11	13.12	168.50
1873	6.33	0.25	0.13	2.18	3.92	13.20	12.50	10.69	10.91	14.30	11.77	0.94	87.12
1874	5.33	1.34	3.94	18.02	8.92	15.87	13.62	17.28	8.22	16.65	20.62	7.89	137.70
1881	......	......	1.08	2.52	10.04	15.28	12.24	6.46	6.30	12.91	22.13	10.35	......
1882	1.65	1.10	1.69	1.73	13.23	18.90	19.10	13.94	10.63	14.96	22.09	5.08	124.10
1883	1.85	0.47	0.55	1.77	11.85	10.08	13.39	25.43	11.14	16.77	11.10	10.94	115.34
1884	3.39	0.39	0.39	4.33	10.16	10.32	15.59	13.27	9.37	8.66	7.05	3.62	86.54
1885	0.87	0.59	0.55	1.34	7.91	16.61	22.99	20.32	17.44	7.99	24.17	25.51	146.29
1886	2.13	5.00	9.17	1.58	13.15	16.38	11.10	12.20	7.52	14.33	21.89	22.72	137.17
1887	2.01	0.67	0.47	10.63	10.28	16.50	17.05	16.89	15.63	19.61	31.81	13.33	154.88
1888	0.63	1.58	1.26	......	......	......	......	......	......	......	......	......	......
1889	......	......	......	......	......	......	......	......	......	......	......	......	......
1890	7.24	1.02	2.01	2.99	9.76	17.24	10.24	20.51	22.99	21.77	19.49	19.06	154.32
1891	2.52	0.51	1.50	0.51	23.00	7.99	14.02	15.98	17.48	17.48	19.49	4.25	124.73
1892	0.98	2.01	3.98	5.00	18.03	16.97	21.77	15.98	16.26	6.69	26.30	11.30	145.27
1893	1.73	3.82	1.81	8.07	6.58	12.32	11.50	15.12	9.92	12.28	17.80	30.94	131.89

Monthly rainfall at Colon—Continued.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1894....	5.35	1.65	0.85	2.16	9.85	12.24	19.10	23.03	18.78	12.40	23.66	25.12	158.69
1895....	3.86	1.89	2.09	21.73	16.77	9.25	17.09	14.13	12.09	16.46	20.47	15.71	151.54
1896....	4.02	1.30	2.01	9.02	16.46	8.50	13.58	15.51	12.84	13.98	15.63	18.66	131.51
1897....	3.42	0.04	0.28	3.74	16.34	18.82	14.06	17.24	17.20	5.83	22.16	18.90	138.03
1898....	5.04	0.35	1.58	4.72	12.83	16.38	21.89	10.91	10.24	11.38	12.28	7.95	115.55
1899....	6.93	6.49	1.26	0.43	13.90	6.41	27.68	14.80	16.55	15.04	14.49	9.04	133.02
1900....	6.06	0.33	1.06	0.75	12.25	11.65	16.81	17.04	9.37	16.33	20.28	4.13	116.06
Mean..	3.56	1.52	1.55	4.42	12.27	13.46	16.92	15.53	12.77	14.20	20.56	12.49	129.25

Monthly rainfall at Bohio, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1896....	....	....	....	....	15.63	8.54	5.55	....	25.51	13.35	17.05	....	....
1897....	....	....	3.07	8.11	18.54	14.10	15.83	25.20	17.48	26.02	19.57	22.05	....
1898....	12.36	1.26	3.03	10.59	14.61	19.76	34.96	38.31	13.31	28.23	21.81	6.38	204.61
1899....	9.37	4.49	3.28	1.10	10.35	14.80	17.76	12.99	8.90	19.33	10.43	6.18	118.98
1900....	7.06	0.48	1.04	2.89	7.42	18.40	17.79	14.02	15.40	18.43	24.98	4.02	131.93
Mean..	9.60	2.08	2.60	5.67	13.31	15.12	18.38	22.63	16.12	21.07	18.77	9.66	155.01

Monthly rainfall at Gorgona, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1896....	....	....	....	....	9.02	6.81	5.16	8.98	13.35	10.94	14.37	....	....
1897....	....	0.08	....	2.60	25.12	13.54	9.65	16.93	15.98	14.41	7.16	7.91	....
1898....	3.42	0.20	0.00	1.38	5.04	4.37	18.50	19.88	....	7.72	9.61	3.94	....
1899....	3.78	2.01	3.31	....	....	....	....	....	....	....	....	4.58	....
1900....	2.63	0.13	0.20	3.15	7.07	12.48	19.72	11.04	11.25	11.93	....	....	....
Mean..	3.28	0.60	1.17	2.38	11.56	9.30	13.26	14.21	13.53	11.25	10.38	5.48	96.40

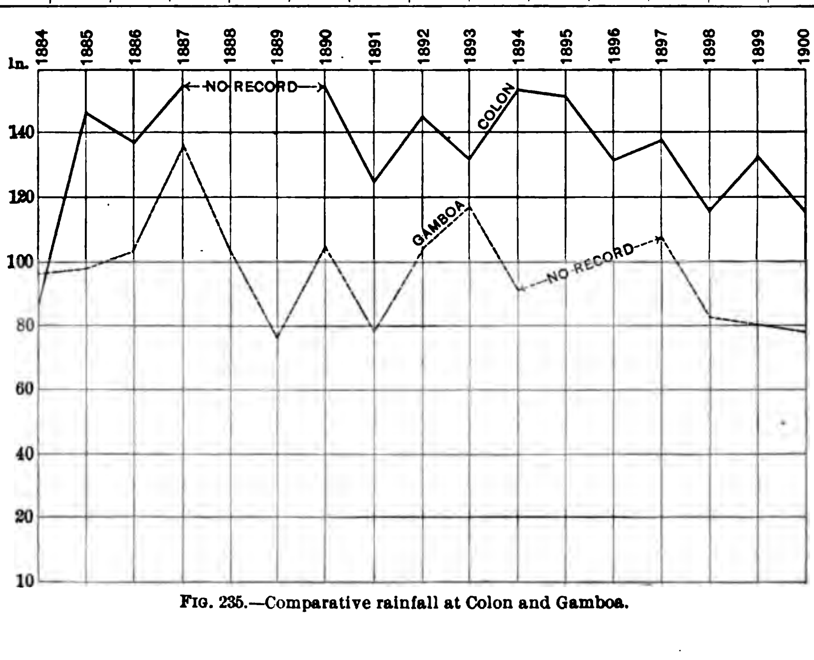


Fig. 235.—Comparative rainfall at Colon and Gamboa.

Monthly rainfall at Gamboa, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1881	....	....	....	....	....	10.63	12.40	9.17	10.89	11.06	12.95	4.76	....
1882	....	....	0.51	1.50	15.47	6.26	10.12	9.88	11.81	8.15	11.81	1.88	....
1883	....	....	....	2.60	9.68	11.02	6.54	15.94	4.13	10.04	7.01	6.30	....
1884	....	0.71	0.28	6.46	6.18	13.35	9.62	16.50	10.55	22.36	6.18	2.20	....
1885	0.20	0.20	0.00	1.38	11.06	10.35	9.06	15.51	16.10	9.33	13.23	11.06	97.48
1886	0.55	1.06	0.71	2.76	15.71	10.55	11.69	16.38	9.13	13.62	16.10	4.61	102.87
1887	2.20	0.08	0.28	6.85	11.02	19.45	14.02	19.17	11.50	14.88	24.06	16.28	136.19
1888	0.12	0.63	0.35	1.26	20.47	11.93	3.27	10.24	12.28	9.57	16.18	16.34	102.64
1889	1.97	4.53	1.42	0.00	4.37	9.10	7.28	10.51	11.42	13.07	8.70	3.35	75.72
1890	4.06	0.35	2.36	3.03	13.27	11.65	10.43	15.35	8.90	21.41	9.92	4.29	105.03
1891	0.63	0.00	0.35	2.13	7.48	9.29	6.06	8.50	10.47	15.71	10.67	6.38	77.67
1892	1.10	0.67	2.56	4.72	16.81	8.54	13.98	14.33	13.74	11.10	10.24	6.58	104.37
1893	0.67	1.06	0.71	7.44	11.89	10.71	15.87	7.95	10.24	16.50	13.90	20.87	117.81
1894	1.46	0.16	0.04	1.34	10.94	8.78	10.08	8.42	15.16	15.28	10.67	8.27	90.60
1895	....	....	....	....	....	....	....	....	....	....	....	....	....
1896	....	....	....	....	3.35	3.31	5.79	....	....	....	....	....	....
1897	....	0.20	0.28	3.23	17.44	12.64	9.10	17.20	18.82	12.80	5.91	8.62	....
1898	2.76	0.12	0.00	1.42	5.82	4.65	18.43	20.16	4.10	8.70	14.57	2.40	82.60
1899	5.00	1.73	1.34	1.42	8.54	8.78	9.45	10.95	13.46	7.95	8.70	2.68	80.00
1900	1.01	0.16	0.13	3.21	6.76	12.15	13.45	8.92	9.24	12.11	10.67	0.79	78.60
Mean	1.67	0.78	0.71	2.99	10.88	10.17	10.35	13.06	11.19	12.98	11.74	7.06	93.58

Monthly rainfall at Bas Obispo, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1884	1.10	0.35	0.35	2.16	3.86	11.97	8.46	10.51	13.98	12.40	6.93	2.64	74.71
1885	0.24	0.12	0.00	1.14	7.36	8.74	6.34	12.84	12.87	8.94	11.10	11.50	81.23
1886	0.83	0.87	0.87	1.69	17.44	12.91	9.02	8.27	10.20	9.37	15.63	3.90	91.00
1887	2.28	0.00	0.12	3.19	10.16	15.43	10.87	8.03	10.98	7.36	14.06	15.79	98.27
1888	0.16	0.51	0.32	0.91	11.58	11.93	1.93	7.76	7.13	3.82	10.59	10.08	66.72
1889	0.79	0.32	1.10	6.50	4.57	9.84	6.42	8.98	13.46	13.23	8.54	3.78	77.53
1890	4.53	0.12	2.56	2.56	13.07	14.96	9.88	12.16	13.03	4.80	6.54	7.95	92.16
1891	6.10	0.00	0.35	2.16	5.83	11.54	6.10	7.76	12.32	14.49	8.35	8.72	83.82
1892	0.79	0.63	2.56	4.76	15.16	10.51	13.10	11.93	17.36	10.28	11.02	6.97	105.07
1893	0.55	1.34	0.71	3.19	19.57	10.75	14.37	9.57	10.63	19.84	13.35	19.13	123.00
1894	1.97	0.32	0.20	1.38	11.89	10.00	10.59	....	....	....	....	....	....
Mean	1.76	0.42	0.83	2.69	10.95	11.69	8.83	9.78	12.20	10.45	10.61	9.05	89.26

Monthly rainfall at Culebra, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec	Total.
1883[a]	....	....	....	1.26	11.50	10.32	....	10.71	5.47	....	....	5.04	....
1884	0.20	0.04	0.67	3.78	....	....	10.24	13.62	8.70	10.12	11.18	1.46	....
1885	0.28	0.00	0.00	1.61	15.39	....	4.29	5.35	11.38	10.63	7.20	....	....
1886	0.43	0.55	0.16	1.18	13.78	12.64	14.33	8.19	7.36	20.63	14.29	5.43	98.97
1887	3.15	0.00	0.04	3.50	7.91	9.96	6.10	8.74	7.64	9.65	12.13	7.95	76.77
1888	0.24	0.04	0.51	0.35	11.42	7.99	2.91	6.54	11.26	5.75	9.53	7.72	64.25
1894	....	....	....	....	....	....	....	....	12.13	13.50	13.23	....	....
1895	....	0.75	....	....	....	....	....	....	....	....	....	....	....
Mean	0.86	0.23	0.28	1.95	12.00	10.23	7.57	8.86	9.13	11.71	11.26	5.52	79.60

[a] Observations at Emperador.

Monthly rainfall at Panama, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1879....	0.04	2.52	5.71	5.55	10.28	6.46	7.91	7.24	9.02	9.80	19.21	0.98	84.78
1880....	1.89	0.12	0.16	1.61	4.45	5.00	9.88	11.46	7.91	11.81	6.46	5.51	66.26
1881....	0.16	0.16	0.35	3.23	10.35	13.78	7.20	4.49	8.94	9.68	9.72	2.48	70.55
1882....	0.00	0.12	0.00	0.98	5.24	6.18	5.35	4.05	4.05	6.69	10.91	2.01	45.60
1894[a]...	......	......	......	......	......	7.48	12.72	6.42	7.32	10.51	6.73	8.27	......
1895[a]...	1.38	0.08	......	......	......	......	......	......	......	......	......	......	......
1899[a]...	......	......	......	......	......	......	......	......	6.14	11.98	8.92	4.35	......
1900[a]...	0.76	0.00	0.00	2.24	11.21	8.91	15.81	5.99	......	......	......	......	......
Mean..	0.70	0.60	1.24	2.72	8.31	7.97	9.81	6.61	7.28	10.08	10.32	3.93	69.52

[a] Observations at La Boca.

Monthly rainfall at Naos, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1881....	......	......	......	......	......	......	......	......	......	......	7.48	2.87	......
1882....	0.00	0.04	0.04	.94	4.53	5.08	1.61	1.14	1.14	2.72	5.04	2.84	25.12
1883....	0.59	0.00	0.00	1.93	4.45	2.56	5.47	5.51	4.64	4.25	7.24	3.11	39.76
1884....	2.01	0.04	0.00	.94	4.84	4.17	4.65	2.99	5.71	8.31	8.62	1.34	43.62
1885....	0.55	0.20	0.00	.91	2.56	5.63	2.64	5.51	4.17	9.96	4.37	4.92	41.42
1886....	0.00	0.28	1.81	1.92	5.20	6.26	9.61	5.91	20.75	6.10	4.49	3.74	66.06
1887....	0.79	0.04	0.04	2.36	5.24	9.88	4.06	6.69	6.97	7.05	8.82	5.59	57.52
1888....	0.08	0.00	0.04	.28	5.55	4.88	2.01	5.71	8.58	8.11	4.02	1.30	40.56
1889....	0.00	0.00	0.91	4.41	5.79	5.43	......	......	......	......	......	......	......
Mean..	0.50	0.08	0.35	1.71	4.77	5.49	4.29	4.78	7.42	6.64	6.26	3.21	45.50